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Analysis & Technology, Inc.
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16. Abstract

Since September 1978 three controlled visual detection experiments providing 966 target detection opportunities in 322 searches have been conducted by the U.S.C.G. Research and Development Center. These experiments involved 82 and 95-foot cutters, 41 and 44-foot boats, helicopters, and fixed wing aircraft searching for 16-foot boat and life raft targets.

This report compares the detection performance of these search and rescue units (SRUs) with the probability of detection (POD) curves of the National Search and Rescue Manual, and recommends revised predictions based upon these results.

Experiment results indicate that actual SRU detection performance falls below that of the present SAR Manual POD curves (based upon the inverse cube law of detection) and above that of the uniform random search curve.

Recommendations are also provided for methods to predict POD directly from probability of detection versus lateral range curves for use with the Computer-Assisted Search Planning (CASP) model.

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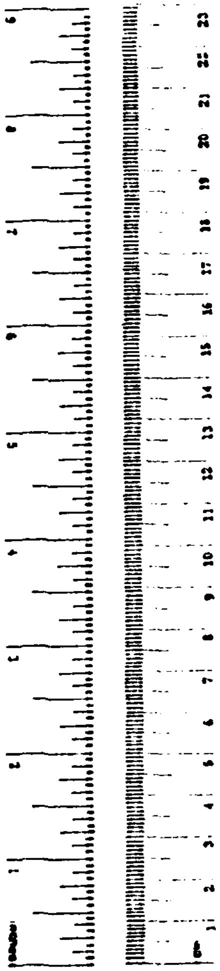
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

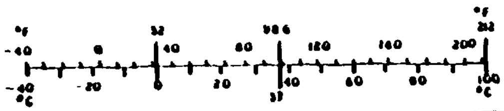


TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

INTRODUCTION

Coast Guard search planners currently use the National Search and Rescue Manual (Reference 1) probability of detection (POD) curves to predict search and rescue unit (SRU) detection performance. These curves are based upon work done during World War II by the U.S. Navy Operations Evaluation Group (OEG) (Reference 3). Among the assumptions associated with this theoretical model are uniform coverage of the search area and the instantaneous probability of detection being inversely proportional to the cube of the sighting range.

Visual detection experiments, conducted by the Coast Guard Research and Development (R&D) Center during 1978 and 1979 primarily to develop improved sweep width predictions, provided 966 life raft and 16-foot boat targets of opportunity from 322 searches. This report compares the demonstrated search ability of cutters, boats, helicopters, and fixed wing aircraft to the SAR Manual predictions in order to evaluate the need for alternative predictive models.

RESULTS

Figure 1 shows plots of experimental detection results, the SAR Manual inverse cube law model, a "lower bound" model (random search curve), and two alternative models. The empirical data is based upon actual detection performance and sweep width estimates reported in Reference 2. Regression analysis indicated that the alternative models were much better fits to the experimental data than either of the two theoretical curves.

For lower coverage factors[1] (0.8 or less), the data is well represented by the inverse cube law model, while for higher coverage factors (greater than 0.8) the empirical data falls between the inverse cube law and the random

[1]Coverage factor = $\frac{\text{Sweep width (W)}}{\text{Track spacing (S)}}$

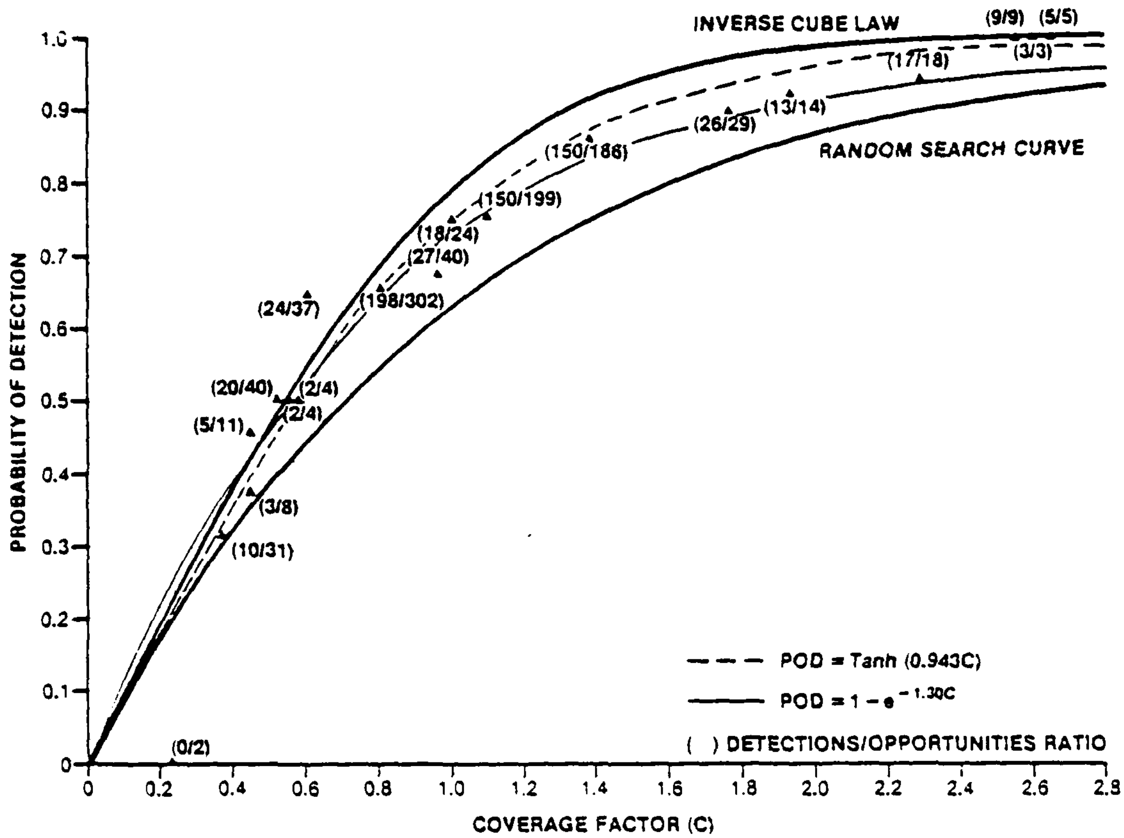


Figure 1. Comparison of Experimental Results to POD Model (All SRUs)

search curve. The lower observed detection performance is attributed primarily to navigational inaccuracies of search units and other operational factors which lead to non-uniform coverage of the search areas.

CONCLUSIONS

a. The present SAR Manual POD versus coverage factor model overestimates POD, particularly at higher coverage factors. Therefore, there is a clear need to revise the SAR Manual model.

b. With the development of empirically derived lateral range curves, the standard method of determining POD should utilize these lateral range curves by driving them through the search area and determining the expected value of POD directly. The Computer-Assisted Search Planning (CASP) System should be used to accomplish this and a manual version of the CASP model should replace the present POD prediction method in the National SAR Manual. It is necessary that any backup manual POD model provide predictions consistent with the standard computerized technique.

RECOMMENDATIONS

a. For use with the CASP model, it is recommended that a method which determines POD directly from lateral range curves, navigation error distribution, and target distribution be implemented. POD predictions generated from the CASP model can then be compiled in a form suitable for a manual/calculator method as a backup to CASP.

b. Because navigation limitations are expected to influence POD, a method for quantifying these effects should be developed and validated.

c. In the future, alternative search tactics should be evaluated. To support this evaluation, further analysis of empirical POD results should be conducted to compare predictions and empirical data for targets between adjacent tracks to predictions and empirical data for those targets near search area borders.

Chapter 1
INTRODUCTION

1.1 SCOPE

This report compares the results of visual detection experiments performed by the Coast Guard Research and Development (R&D) Center during 1978 and 1979 with the cumulative probability of detection (POD) versus coverage factor (C) curves found in the National Search and Rescue Manual (Reference 1). Recommendations for future efforts in developing a computer-aided POD model and a backup manual POD prediction method are made. The curves are presently used by search and rescue (SAR) planners to predict a search and rescue unit's (SRU's) POD for a search under specific environmental conditions and for a given track spacing (S).

1.2 BACKGROUND

The empirical data (966 target opportunities in 322 searches) used for this report were gathered during a series of three controlled experiments conducted by the Coast Guard R&D Center during 1978 and 1979. The major goals of these experiments were: (a) the generation of revised sweep width tables for the SAR Manual and lateral range curves for the Computer-Assisted Search Planning (CASP) model based upon the results of carefully monitored experiments,[1] (b) evaluation of the current POD model, and (c) proposal of changes to the POD model, where appropriate. This report deals with the latter two goals. In order to make these assessments, it is first necessary to examine the concepts of sweep width and coverage factor as they relate to the prediction of POD.

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[1]For a detailed discussion of experimental results as they relate to the updating of sweep width tables, see Reference 2.

1.2.1 Sweep Width

Effective SAR operations require efficient use of limited SAR resources. Optimal use of available SRUs benefits the Coast Guard by conserving human and material resources while providing the best chance for saving life and property.

At present, SAR planners use information concerning on-the-scene environmental conditions, target characteristics, and SRU type to calculate a quantity known as sweep width (W) for a given search.

Sweep width is a performance measure for search units. It is a single-number summation of a more complex range detection probability relationship. Mathematically,

$$\text{Sweep Width } (W) = \int_{-\infty}^{+\infty} P(x)\, dx \qquad (1)$$

where

x = lateral range or closest point of approach of targets of opportunity (see Figure 1-1) and

$P(x)$ = probability of detection at lateral range x.

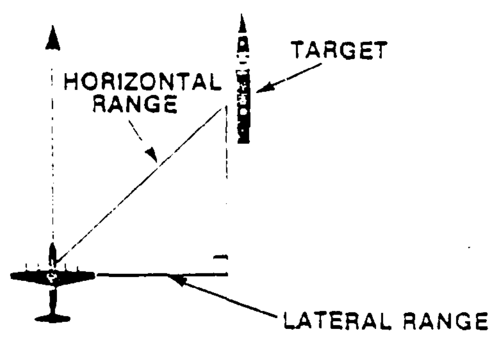


Figure 1-1. Definition of Lateral Range

Figure 1-2 shows a typical P(x) curve as a function of lateral range (Reference 1), where x is the lateral range of detection opportunities.

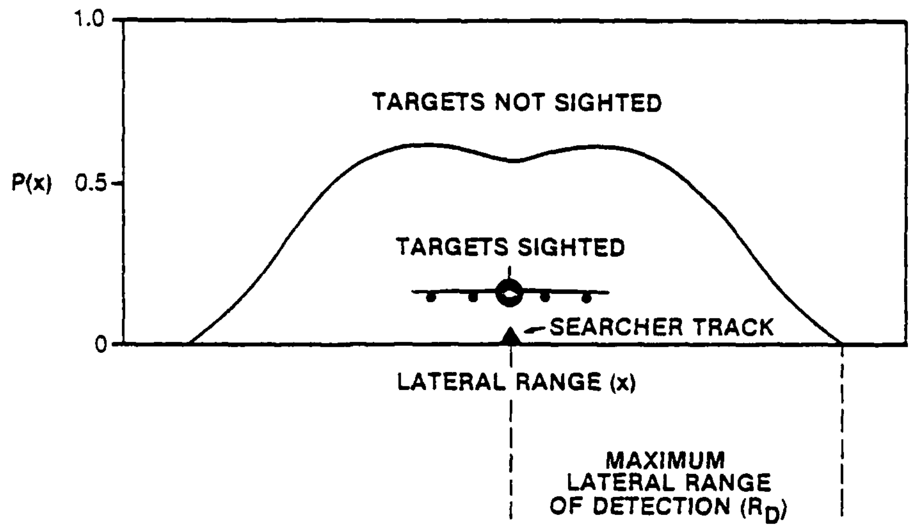


Figure 1-2. Relationship of Targets Sighted to Targets Not Sighted

In concept, sweep width is the numerical value obtained by reducing the maximum lateral range of detection (R_D) of any given sweep so that scattered targets which may be detected beyond the limits of W are equal in number to those which may be missed within those limits. Figure 1-3 graphically presents this concept of sweep width. The number of targets missed inside the sweep width distance is indicated by the shaded portion near the top middle of the rectangle (area A) while the number of targets sighted beyond the sweep width distance is indicated by the shaded portion at each end of the rectangle (area B). Referring only to the shaded areas, when the number of targets missed equals the number of targets sighted (area A = area B), sweep width is defined. A detailed mathematical development and explanation of sweep width can be found in Reference 3.

Sweep width is dependent on a variety of environmental factors as well as on the SRU type and on the target characteristics. A detailed discussion of the effects which environmental parameters have on sweep width for various SRU and target types can be found in Reference 2.

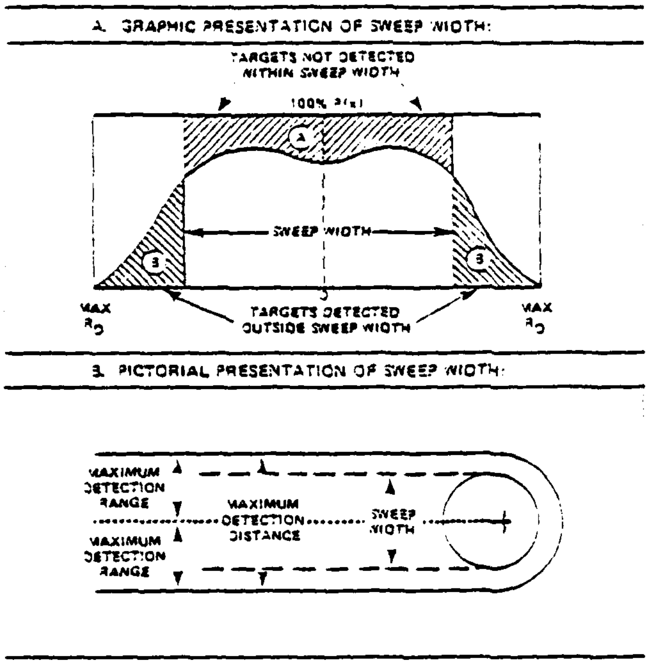


Figure 1-3. Graphic and Pictorial Presentation of Sweep Width

1.2.2 Coverage Factor

Once sweep width has been determined, a track spacing is assigned to each SRU so that a desired POD is predicted for the search by the POD versus coverage factor curves of Reference 1. The track spacing is calculated by entering these curves (shown in Figure 1-4) with the desired POD, and obtaining the corresponding coverage factor required. Coverage factor (C) is simply the ratio of sweep width to track spacing:

$$C = \frac{W}{S} \qquad (2)$$

From the above relationship, track spacing can be determined for a given sweep width so that the desired coverage factor is obtained.

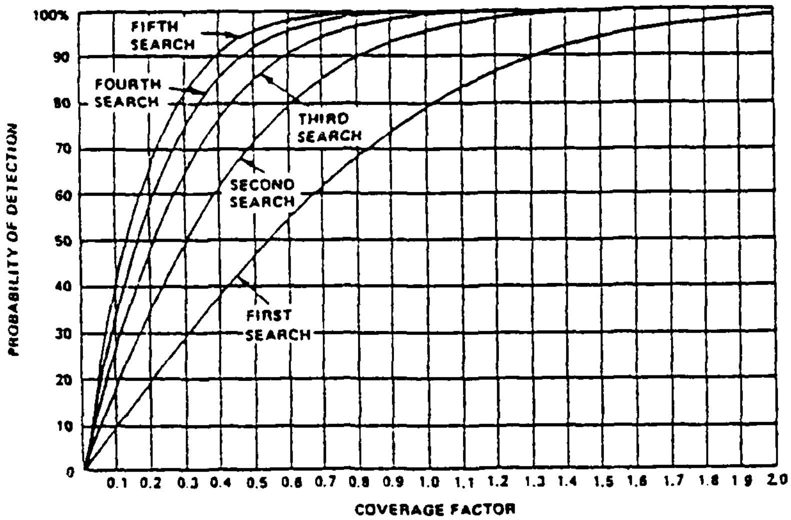


Figure 1-4. Probability of Detection Versus Coverage Factor Curve

It is apparent from the above discussion that effective search planning relies heavily upon the accuracy of the present POD versus coverage factor model. If this model cannot be validated empirically, then it should be changed appropriately to improve its effectiveness as a search-planning tool.

1.2.3 Inverse Cube Law of Detection

The inverse cube law of detection states that instantaneous glimpse probability of detection (γ) for a target is given by:

$$\gamma = \frac{kh}{r^3} \tag{3}$$

where:

k = a constant which depends on target's area and intrinsic contrast with background,

h = altitude of searcher, and

r = horizontal range to target (see Figure 1-1).

It can be shown (see Reference 3) that, for continuous looking, the cumulative probability of detection (POD) as a function of time is given by:

$$POD = 1 - e^{-\int_0^t \gamma (t)\, dt} \quad (4)$$

From the above expressions it can ultimately be shown that, for a parallel sweep search, the cumulative probability of detection equation is:

$$POD = \frac{2}{\sqrt{\pi}} \int_0^z e^{-z^2}\, dz = \mathrm{erf}(z) \quad (5)$$

where $z = \frac{\sqrt{\pi}}{2} \frac{W}{S}$.

This equation is derived in detail in Reference 3, and forms the basis of the curves presented in Figure 1-4.

Inherent in the use of equation 5 are several assumptions about target location within the search area, the manner in which the area is searched, and the geometry between searcher and target. These assumptions include:

a. The target is located randomly within the search area and remains in the area for the entire search.

b. The area is covered by equally-spaced, parallel search tracks.

c. Constant environmental conditions (i.e., constant sweep width for any SRU or target type) prevail over the duration of the search.

d. Constant search speed is maintained.

e. A number of "passes" are made on both sides of the target by the searcher.

f. The instantaneous probability of detecting (γ) the target is dependent on the surface area and intrinsic contrast of the target.

g. The altitude h of the searcher is small compared with the range to the target.

Chapter 3 discusses the extent to which these assumptions were met during the visual detection experiments and actual SAR missions. The extent to which deviations from these assumptions may cause differences between predicted and actual results is discussed in Chapter 4.

1.2.4 Uniform Random Search

The uniform random search model represents the case where the least information is known about the target and no systematic search plan is used. It can be shown that for this case POD = $1 - e^{-W/S} = 1 - e^{-C}$ (see Reference 4 for a derivation of this relationship). Figure 1-5 shows the relationship between the predictions of the inverse cube law and uniform random search models. As would be expected, the inverse cube law provides higher predictions of POD for the same coverage factor than the random search model because a systematic means of searching is assumed.

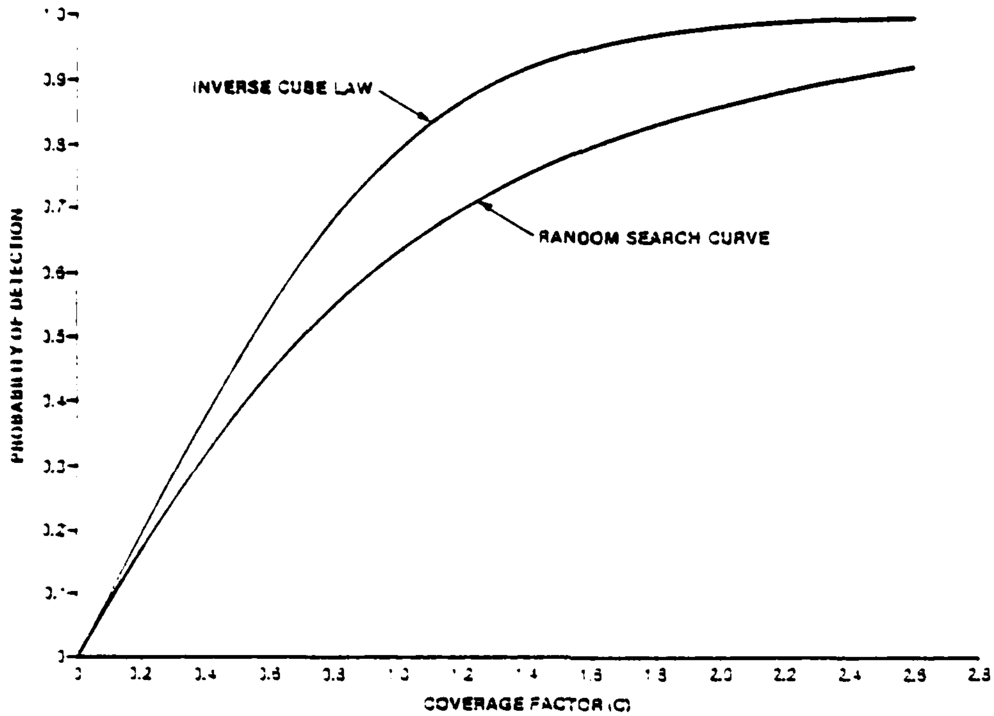


Figure 1-5. Comparison of Inverse Cube Law and Uniform Random Search Models

Chapter 2
CONDUCT OF EXPERIMENTS

2.1 INTRODUCTION

The following sections describe the controlled experiments which provided the basis for this report.

2.2 GENERAL DESCRIPTION OF EXPERIMENTS

2.2.1 Time Frame

Data were gathered during experiments conducted from 11 September to 6 October 1978, 16 April to 22 May 1979, and 17 September to 25 October 1979. These time frames provided a reasonable mix of weather conditions while avoiding interference from summer air and surface traffic.

2.2.2 Location

All three experiments were conducted in Block Island Sound (Figure 2-1) in areas ranging from 60 to 300 square nautical miles depending upon SRUs involved and prevailing environmental conditions.

Whenever possible, searches were conducted in the same manner as actual SAR missions. Twenty-four hours prior to each search, the Coast Guard R&D Center released a SAR exercise (SAREX) message to all SRUs involved providing detailed information necessary to conduct the desired visual searches. These SAREX messages defined the search area, assigned search patterns and track spacing, and provided other information that would be essential during actual SAR missions.

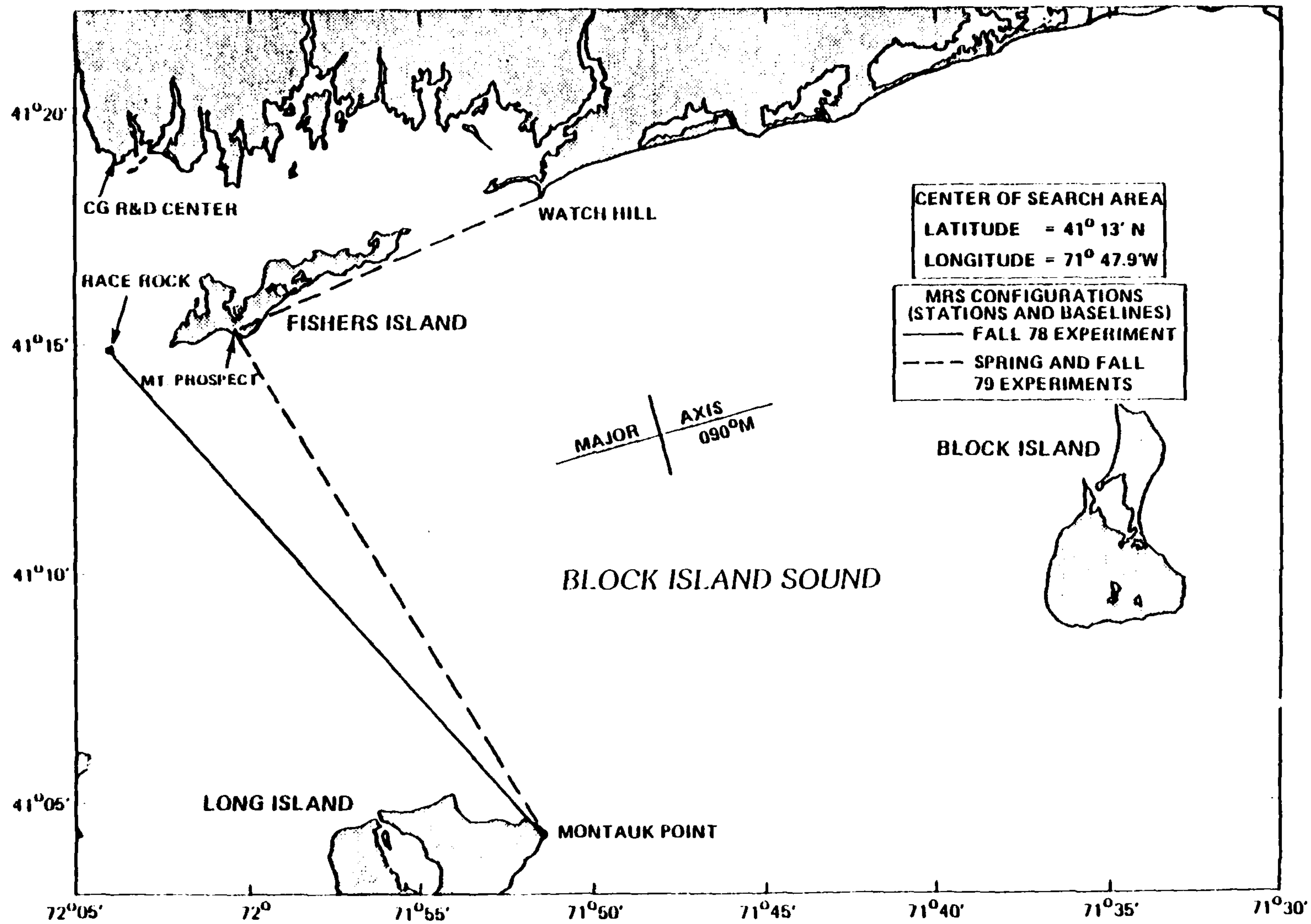


Figure 2-1. Search Area and MRS Configuration

2.2.3 Participants

Numerous surface vessels and aircraft participated in the visual detection experiments. A brief description of the characteristics of each type of SRU and a list of the individual participants are given in Tables 2-1 and 2-2.

Table 2-1. Search Unit Characteristics

SRU Type	Crew Size	Maximum Speed (knots)	Navigation Equipment	Height of Eye (ft)
SAR boats				
41 ft	3	20	DF[1,2], Radar, Fathometer	10
44 ft	3	10	DF[1,2], Radar, Fathometer	10
Cutters				
82 ft	8	18	LORAN A or C, Radar, DF[1,2], Fathometer	25
95 ft	12	15	LORAN A or C, Radar, DF[1,2], Fathometer	20
Helicopters				
HH-52A	3	90	TACAN, LORAN C[2]	--
HH-3F	4	115	TACAN, LORAN A, Doppler Computer, Radar	--
Fixed wing aircraft				
HU-16E	5	145	TACAN, Radar, LORAN A or C	--
HC-130	9	300	TACAN, Radar, LORAN A, INS[3]	--

[1]Direction Finder.
[2]Not used in experiments.
[3]Inertial Navigation System.

Table 2-2. Participating Units/Facilities

CG Light Station Montauk, NY
CG Light Station Race Rock, New London, CT
CG Light Station Watch Hill, RI
Naval Underwater Systems Center (NUSC) FORACS Facility, Fishers Island, NY

CG Air Station Brooklyn, NY: CG 1442, CG 1368, CG 1424, CG 1391, CG 1410, CG 1388, CG 1384 (HH 52A)
CG Air Station Cape Cod, Otis AFB, MA: CG 1473, CG 1479, CG 1484 (HH 3F); CG 7254, CG 7250, CG 1293, CG 7213, CG 7214, CG 1016 (HU-16E)
CG Air Station Clearwater, FL: CG 1351, CG 1340 (HC-130B)
CG Air Station Elizabeth City, NC: CG 1340, CG 1347, CG 1344, CG 1346, CG 1341 (HC-130B); CG 1504 (HC-130H)

CGC Cape Fairweather (WPB 95314), New London, CT
CGC Cape George (WPB 95306), Falmouth, MA
CGC Cape Horn (WPB 95322), Woods Hole, MA
CGC Point Bonita (WPB 82347), Falmouth, MA
CGC Point Jackson (WPB 82378), Woods Hole, MA
CGC Point Knoll (WPB 82367), New London, CT
CGC Point Turner (WPB 82365), Newport, RI
CGC Point Wells (WPB 82343), Montauk, NY

CG Station Block Island, RI: CG 41441, CG 44349
CG Station Montauk, NY: CG 41342, CG 44348
CG Station New London, CT: CG 41413, CG 41337, CG 41350
CG Station Point Judith, Narragansett, RI: CG 41385, CG 44352, CG 44321, CG 44349

2.2.4 Navigation

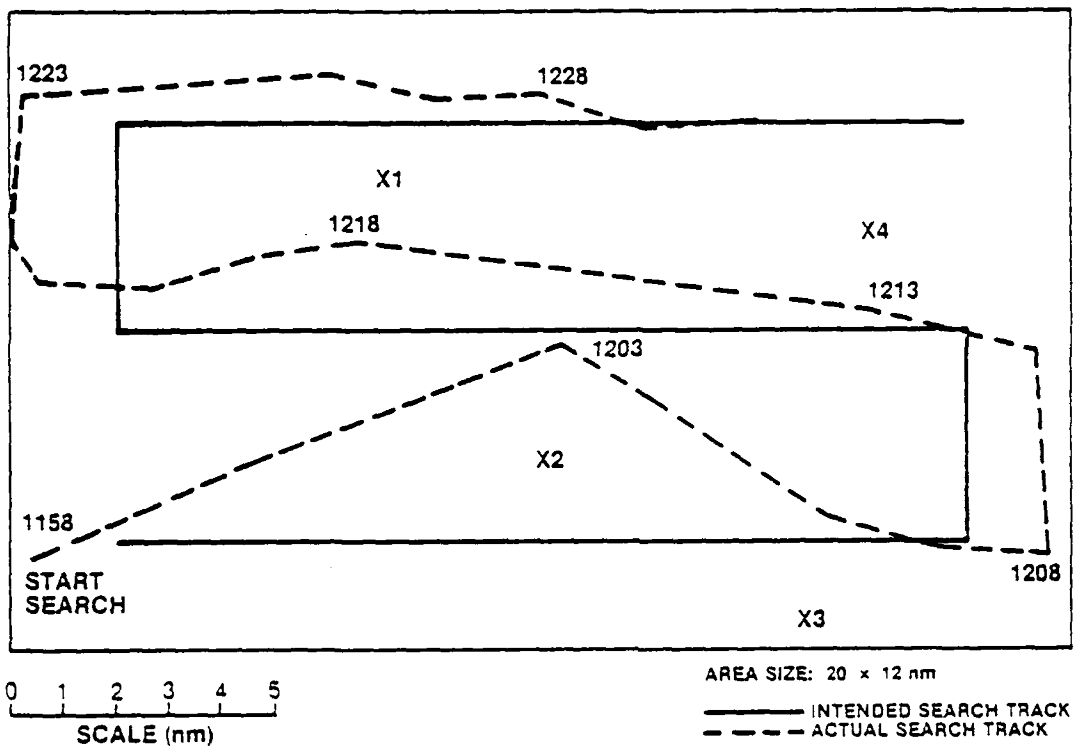
Navigation techniques used to execute assigned search tracks varied for each SRU type. The HU-16 aircraft generally used LORAN A or C, HC-130 aircraft used an inertial navigation system (INS), and helicopters used TACAN when altitude and conditions permitted. In addition to TACAN, HH-3 helicopters used a navigational computer which input LORAN A, Doppler and TACAN during their searches. Cutters generally used LORAN C navigation while 41- and 44-foot boats were usually limited to dead-reckoning with periodic visual and radar fixes. Table 2-1 summarizes the navigational equipment available to each type of SRU during the experiments.

A qualitative review of representative SRU tracks indicated that cutters with LORAN C navigated most accurately while aircraft relying upon TACAN or LORAN A had the most difficulty in navigating the search area. Figure 2-2 shows an example of an HU-16E fixed wing aircraft search using LORAN A.

2.2.5 Search Tracks

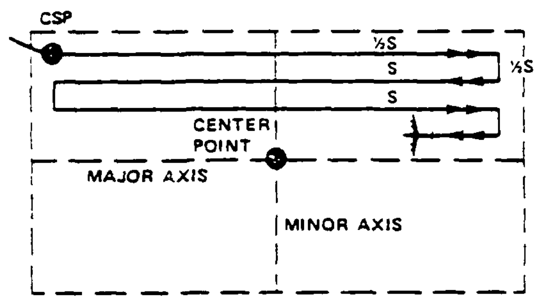
Search unit tracks were laid out in the same manner as actual SAR missions. Two basic search patterns were used: parallel (Sketch 1) and creeping line (Sketch 2) (Reference 1). To make best use of onboard navigational equipment, some units slightly altered the basic patterns (Sketches 3 and 4).

a. Parallel Search (PS). Search legs were parallel to the direction of the major axis of the search area and were separated by a specified track spacing. Commence search points (CSPs) and outer search legs were one-half the track spacing (S) inside the search area perimeter.



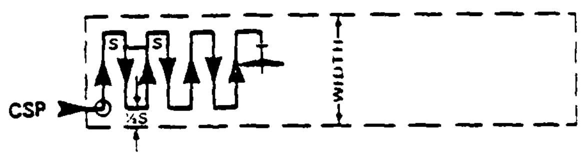
NOTES:
1. HU-16E SEARCHED FOR 16-ft BOAT TARGETS (1,2,3,4) AT 1000-ft ALTITUDE AND 120-knot SEARCH SPEED USING 4-nm TRACK SPACING.
2. ENVIRONMENTAL CONDITIONS: VISIBILITY 4 nm, WIND SPEED 6 knots, CLOUD COVER 100%, SWELL HEIGHT 0 ft.
3. ACTUAL POD OF SEARCH WAS 50%: TARGETS 1 AND 4 WERE SIGHTED, 2 AND 3 WERE MISSED.

(U) Figure 2-2. Actual and Intended LORAN A Search Track for HU-16E (Fixed Wing Aircraft)



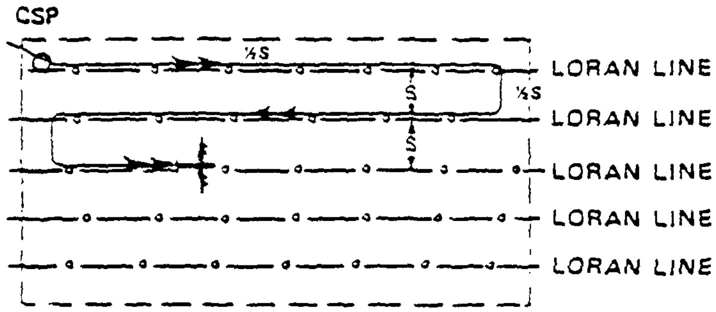
Sketch 1. Parallel Search Pattern

b. Creeping Line Search (CS). Search legs were perpendicular to the direction of the major axis of the search area and were separated by a specified track spacing. Start points and outer search legs were one-half the track spacing inside the perimeter of the search area.



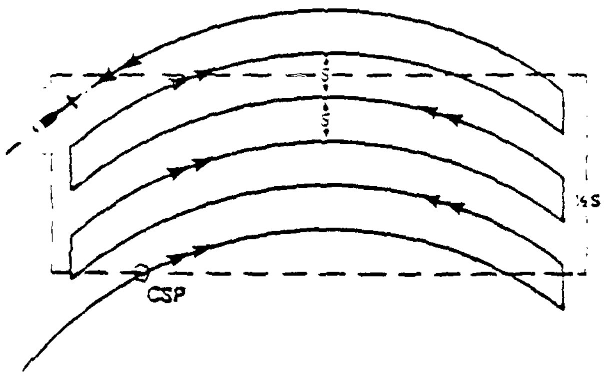
Sketch 2. Creeping Line Search Pattern

c. Cutters with LORAN C (HU-16E with LORAN A). The two basic search patterns were skewed with respect to the major axis so that the cutters could follow LORAN C lines, and the HU-16E could follow LORAN A lines. The basic search patterns assigned were parallel search LORAN (PSL) and creeping line search LORAN (CSL).



Sketch 3. Cutter and Fixed Wing Aircraft Search Pattern

d. Helicopters with TACAN. The two basic search patterns were skewed so that the helicopter could navigate along arcs of constant range from the Norwich TACAN station (modified parallel search) and from the Hampton TACAN station (modified creeping line search). TACAN is a distance measuring navigation net and was one of the means of navigation available for helicopter search.



Sketch 4. Helicopter Search Pattern

2.2.6 Targets

Target types varied from experiment to experiment and included 16-foot blue or white boats and seven-man life rafts (black without canopy or orange with and without canopy). Either boats or rafts were anchored at predetermined locations for each search (see Section 3.4.1). At the beginning and end of each day or whenever targets were relocated, a microwave ranging system (MRS) was used to accurately mark the position of each target.

2.3 MICROWAVE RANGING SYSTEM

In all three experiments, a microwave ranging system (MRS) monitored the positions of SRUs and targets. During the fall 1978 experiment, a master transmitting unit was located at Race Rock Light Station with a secondary transmitter at Montauk Point Light Station. To provide coverage over a larger area and a more consistent performance under poor transmitting conditions, the master station was moved to Fishers Island and another secondary transmitter was added at Watch Hill Light Station for the 1979 experiments. The geometries for both MRS configurations are shown in Figure 2-1. Each SRU (except HC-130 aircraft) was equipped with a transponder which allowed the system to track it. The on-scene commander (OSC) vessel was also equipped with a transponder so that target positions could be marked by the system. To provide data for track reconstruction, the position of surface SRUs was recorded every 3 to 5 minutes and the position of aircraft SRUs was recorded every minute.

For a more detailed discussion of MRS operation, see Reference 2.

2.4 DATA ACQUISITION

Each day, an observer was aboard each SRU to collect data and monitor crew search procedures. As the SRU swept through the area along the assigned track, lookouts reported all target sightings to the observers along with information which would facilitate post-exercise validation of the sightings (search units did not divert from track to identify sightings). To verify sightings, the following information was recorded:

a. Time target was sighted,

b. Approximate range and relative bearing to target,

c. Relative bearing of sun,

d. Searcher course, speed, and altitude,

e. Target description, and

f. Lookout position.

In addition, the OSC and observers periodically collected environmental data, including visibility, wind speed, swell height, sun elevation, and cloud cover. Time on task (search time) was also recorded by the observers on each SRU.

2.5 DESCRIPTION OF EXPERIMENT CONDITIONS

2.5.1 Summary of Detection Opportunities

Table 2-3 provides a summary of the total SRU resources dedicated to the evaluation of the current POD model in terms of search time expended and number of searches conducted. Search time is defined as the cumulative number of hours each SRU type spent searching only during the experiments. The number of searches represents the total number of complete searches conducted by each SRU type. The breakdown of the 966 target detection opportunities is also given for each type of search unit.

Table 2-3. Summary of SRU Resources

SRU Type	Target Type	Total Search Time (hr)	No. of Searches	Total No. of Detection Opportunities
41/44' boats	Boats	101.6	33	138
41/44' boats	Rafts	73.7	29	106
82/95' cutters	Boats	123.2	37	133
82/95' cutters	Rafts	87.8	37	128
Fixed wing aircraft	Boats	37.0	41	114
Fixed wing aircraft	Rafts	30.4	46	105
Helicopters	Boats	44.6	56	145
Helicopters	Rafts	28.5	43	97

2.5.2 Range of Environmental Parameters

An effort was made to conduct these experiments under conditions representative of those experienced during actual SAR missions. Table 2-4 shows the range of environmental conditions that existed during these experiments and the percentage of FY 1979 SAR missions that are represented by these conditions. In general, the environmental conditions not represented in these experiments are the poorer conditions (visibility < 5 nautical miles, wind speeds > 20 knots and swell height > 4 feet). These conditions are not represented in the data base for two reasons:

a. Conditions in the search area at these times of year infrequently reach these extremes and

b. Degradation of conditions much beyond the values above would cause cancellation of the experiment for safety reasons and/or to prevent loss of or damage to the targets.

Table 2-4. Range of Experiment Environmental Conditions

SRU Type	Target Type	Range of Environmental Conditions*		
		Visibility (nm)	Wind Speed (knots)	Swell Height (ft)
Surface craft	Boats	3-20(91)	0-22(98)	0-4(93)
	Life rafts	3-18(91)	0-17(93)	0-2(77)
Aircraft	Boats	5-15(83)	0-20(97)	0-3(87)
	Life rafts	5-15(83)	0-20(97)	0-3(87)

*Numbers in parentheses indicate the percentage of FY 1979 SAR cases involving 16- to 25-foot targets that are represented by the range of environmental conditions experienced during the experiments.

Chapter 3
ANALYSIS APPROACH

3.1 INTRODUCTION

The following sections describe the methods used to reduce the experimental data, and compare the data to theoretical predictions.

3.2 ORGANIZATION OF RAW DATA

Raw data from these experiments consisted of the following:

a. Plots of the actual track followed by each SRU on each search it performed (generated from MRS data). These plots include the locations of all targets set for each search.

b. Plots of the assigned track for each search. These plots were generated using instructions given to each unit in the daily SAREX messages. Instructions included search-area center point and major axis, assigned track spacing, area size, CSP, and search pattern.

c. Data sheets compiled by observers aboard each SRU and the OSC's log for each day. These materials were described in Section 2.4. A more detailed description can be found in Reference 2.

3.2.1 Determining Opportunities and Detections

To be considered a valid opportunity for the POD analysis, a target had to meet the following criteria:

a. It must have been located within the boundaries of the search area.

b. It must have remained in the search area for the full duration of the search.

Any target which met these conditions and was sighted at least once during the search was considered to be a valid detection. The POD for each search was the ratio of detections to opportunities:

$$POD = \frac{\text{number of valid detections}}{\text{number of valid opportunities}}$$

3.2.2 Determining Nature of Target Distribution

To evaluate target distribution, each plot of an assigned search track was divided into a normalized 5 X 5 coordinate grid as shown in Figure 3-1. Both the horizontal and vertical dimensions of the search area were divided into five equal parts. This procedure set up a normalized coordinate system which could be used to compare target locations in a consistent manner over all searches. The distribution of targets with respect to this grid is discussed in Section 4.3.

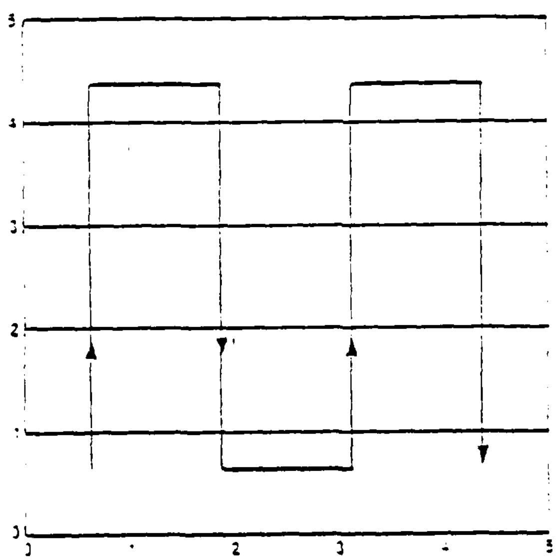


Figure 3-1. Search Area with Normalized 5 X 5 Coordinate Grid

3.2.3 Sorting Data

Raw data was sorted according to SRU type, target type and environmental conditions so that POD versus coverage factor curves could be constructed for each data base. A coverage factor for each search was calculated using the assigned track spacing for the search and a sweep width estimate. These estimates of sweep width were generated based upon the methods used in Reference 2. These sweep width estimates considered all factors previously found to influence lateral range distributions: search unit type, target type, and applicable environmental parameters such as wind speed, swell height, visibility, etc. It is noted that many of these sweep width estimates differ substantially from those in Reference 1 presently used by operating forces. Raw data files containing target detections and misses, coverage factor, environmental conditions, and track spacing for each search can be found in Appendix A.

3.3 EMPIRICAL POD VERSUS COVERAGE FACTOR CURVES

The raw POD versus C data for each SRU type/target type combination was plotted using a computer binning routine which sorts data with the assumption that the dependent variable (POD) is a nondecreasing function of the independent variable (C). This technique, described in Reference 5, is consistent with the expected POD versus C relationship and provides a smooth data set for curve fitting.

Curves were fit to the binned empirical data using a weighted least-squares regression computer routine. Fitting functions evaluated include $POD = 1-e^{-KC}$ and $POD = Tanh(KC)$. These functions were selected for the regression because they exhibit characteristics that search theory predicts for the POD versus C relationship. Characteristics which the fitting function should exhibit include:

a. POD = 0.0 at C = 0.0.

b. POD is asymptotic to 1.0 as C becomes very large.

c. POD is a monotonically increasing function of C.

d. Slope = 1.0 at C = 0.0.

e. Curve is concave downward.

Both fitting functions conform to these characteristics when K equals 1. In cases where K does not equal 1, the slope (item d) becomes equal to K at 0 coverage factor. (Note: $POD = 1-e^{-C}$ is the Random Search Curve function.) The coefficients of determination (R^2) of each function's fit were compared for each of these models and also for the inverse cube law and random search curves. These results are discussed in Section 4.1.

3.4 COMPARISON OF EXPERIMENT CONDUCT WITH THEORETICAL ASSUMPTIONS

One of the more important considerations in comparing experimental detection results with the present detection model was to determine the similarities and differences between the assumptions of the model and the manner in which the experiments were conducted. The experiments were not designed to ensure consistency with POD model assumptions but rather were designed to be conducted like actual SAR missions. Table 3-1 shows the assumptions associated with the POD inverse cube law model, and whether the R&D Center experiments and actual SAR missions were consistent with these assumptions. The following sections discuss these individual differences and their potential influence on POD.

3.4.1 <u>Target Location</u>

The current POD model assumes a random placement of targets within the search area. For the initial experiment, the target distribution was not uniform; there was a greater target density in the center of the search area than on the perimeter. For the two subsequent experiments, an essentially uniform target distribution was developed over the course of the experiments. It is postulated that the target distribution for actual SAR missions is not uniform, but rather, as was the case during the initial experiment, typical

Table 3-1. Comparison of Actual Operations with POD Model Assumptions

Assumptions Associated With Present Inverse Cube Law POD Model	Are Assumptions Met by Actual Operations?	
	R&D Center Experiments	Actual SAR Missions
Target is located randomly within the search area.	1978 Experiment: No 1979 Experiment: Yes	Possibly, most likely higher probability toward center of area
Target remains in area for the entire search.	Yes	Not necessarily, depends on accuracy of target position estimates
Area is uniformly searched by equally spaced parallel sweeps.	No	No
Sweep width remains constant throughout search.	No	No
Searcher makes a number of passes on both sides of target.	Center areas: Yes Perimeter areas: No	Center areas: Yes Perimeter areas: No
Search speed is constant.	Yes	Yes
The altitude of the searcher is small compared to the range to the target.	Surface craft: Yes Aircraft: Yes for ranges > about 1 nm	Surface craft: Yes Aircraft: Yes for ranges > about 1 nm

targets are most likely to be near the center of the area, with the probability decreasing as one moves toward the area boundary. In general, a most-probable position is determined based upon the last reported position of the target, drift, and leeway. Based upon the uncertainties associated with the estimates of the parameters, an area around this datum point is then defined.

3.4.2 Search Methods

The current POD model assumes that the search area is covered by equally spaced parallel sweeps and that a number of passes are made on both sides of the target by the searcher. For the following reasons, deviations from this assumption occur both during the experiments and for actual SAR missions:

a. For those areas farther than S/2 from the search area perimeter, the intended SRU tracks result in each target being between two equally spaced parallel sweeps; however, those targets within S/2 of the perimeter are not covered by equally spaced parallel sweeps. Therefore, these perimeter areas are searched less thoroughly than predicted by the current POD model. However, note that the effect of nonuniformity of this search coverage is reduced if targets are more likely to be located near the center of the area.

b. Probably more important is that SRUs were not able to precisely follow their intended tracks; therefore, the spacing between tracks was not uniform, resulting in some areas being searched either more thoroughly or less thoroughly than intended.

3.4.3 Constant Sweep Width

The current POD model assumes that sweep width remains constant throughout the search. Due to varying environmental conditions, sweep width is a continually changing function. Perhaps more important, sweep width has been found to continually decrease with increases in time on task. Therefore, even if all other parameters remain constant, sweep width will decrease throughout a search resulting in a reduction in the predicted POD.

Chapter 4
RESULTS, CONCLUSIONS AND RECOMMENDATIONS

4.1 GENERAL

Figure 4-1 shows aggregate POD data plotted versus coverage factor. Also plotted are the SAR Manual inverse cube law model, the random search model, and the two fitting functions described in Section 3.3. The most important characteristic of the data is that for coverage factors of 0.8 or less, the inverse cube law provides an excellent representation of the data, while for coverage factors greater than 0.8 the data falls between the inverse cube and random search curves. Overall, either of the two fitting functions used fits the data better than the SAR Manual curve or the random search curve. Therefore, for making comparisons between data sets in later sections, the fitting function that best represents the data will be used. The optimum value of K for each fitting function was determined by maximizing the coefficient of determination (R^2) using a weighted least-squares regression computer routine.

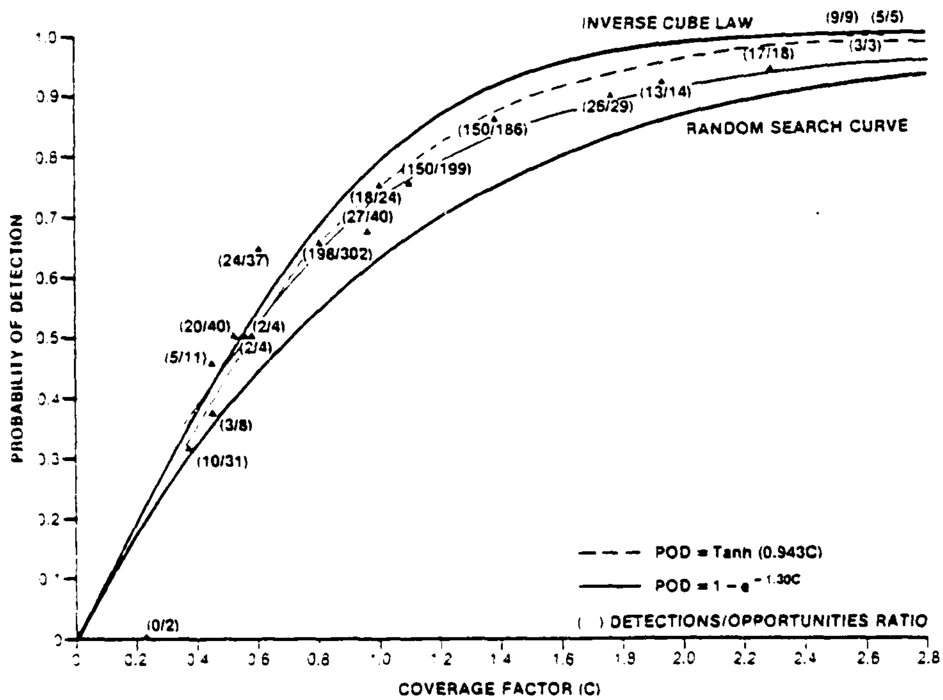


Figure 4-1. Comparison of Experimental Results to POD Models (All SRUs)

Table 4-1 presents the R^2 "goodness-of-fit" measure for both fitting functions and R^2 for the inverse cube law and random search curve. The results are arranged from best fit to poorest fit. These results seem reasonable if one considers the assumptions about the search patterns associated with each model:

Inverse Cube Law	Random Search
Equidistant parallel sweeps of the search area are conducted, beginning at one search area boundary and ending at the opposite boundary.	Search is conducted with no systematic plan or method.

Table 4-1. Goodness of Fit of Models Evaluated

Model	Coefficient of Determination (R^2)
$POD = 1-e^{-(1.30C)}$	0.940
$POD = \text{Tanh}(0.943C)$	0.891
$POD = \text{Tanh}C$	0.861
$POD = 1-e^{-C}$ (Random Search Curve)	0.482
$POD = \text{erf}(\frac{\sqrt{\pi}}{2} C)$ (Inverse Cube Law)	0.352
NOTE: C is coverage factor.	

In practice, the SRUs conducted their searches based upon a systematic plan; therefore, their performance would be expected to be better than the random search prediction. On the other hand, the search patterns assigned did not provide for coverage of perimeter areas (within S/2 from the search area boundaries) with the thoroughness assumed by the inverse cube law. Also, due to navigation limitations, SRUs were not able to implement these patterns exactly as specified by the OSC. Thus, performance lower than that predicted by the inverse cube law is a reasonable result.

The fact that the empirical data closely followed the inverse cube law for coverage factors less than 0.8 and fell between the inverse cube and random search curves for higher coverage factors also appears to be a reasonable result. For low coverage factors the overlap between lateral range curves on adjacent legs is less than for higher coverage factors, and thus similar deviations from the intended search track due to navigational limitations will have less effect on POD as shown in Figure 4-2. On the left is an example of a lower coverage factor (S = 2W), on the right, an example with a higher coverage factor (S = W). Tracks A and B are intended tracks, while Track B' is the track an SRU might follow due to navigation inaccuracies, which would cause the track spacing to increase by an amount X. As these figures illustrate, an increase in the track spacing by X would have a greater effect on the expected value of POD for Case B than Case A (calculated by summing the POD contribution from each track assuming independence). For Case A, the probability of detection at the intersection between the lateral range curves is relatively low even if the intended tracks are followed, so that the incremental reduction in POD caused by the increase in the track spacing by an amount X is small. In contrast for Case B, POD at the intersection of the lateral range curves is relatively high and the point where the curves intersect is the region of maximum slope. Therefore, an increase in track spacing by the same amount X would cause a greater reduction in POD than would be expected for Case A. Note that the magnitude of this effect is sensitive to the slope of the lateral range curve. Sensitivity to lateral range curve shape will be discussed in Section 4.4.

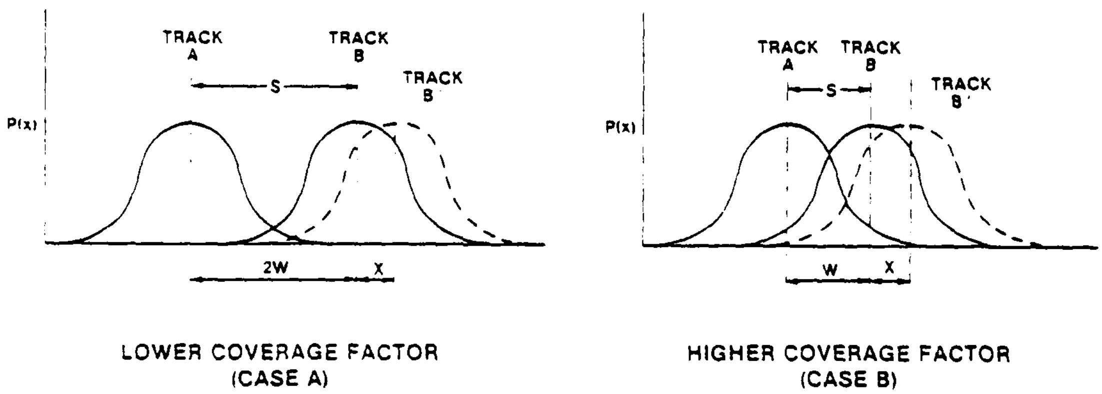


Figure 4-2. Effect of Deviations from Track on POD

4.2 COMPARISON OF RESULTS BY SRU TYPE

SRU types differ with respect to navigational capabilities, and the shape of their lateral range curves for a specific set of search conditions. Because of these differences, it is postulated that a unique POD model fit is appropriate for each SRU type. This hypothesis was tested in a preliminary manner by comparing the best-fit POD model for each SRU type (see Table 4-2). As shown in Figure 4-3, all models fall between the random search and inverse cube models. While differences exist between the best-fit models for each SRU type, these differences are not statistically significant at the 90-percent confidence level. Further investigation into POD differences for various SRU and navigational equipment combinations should be conducted to better quantify the effect of SRU type on detection performance. Suggestions for this investigation are made in Section 4.5.

Table 4-2. POD Model Fits by SRU Type

SRU Type	POD = Tanh(KC)		$POD = 1-e^{-KC}$	
	K	R^2	K	R^2
41'/44' boats	1.055	0.936	1.467	0.912
82'/95' cutters	0.984	0.879	1.397	0.838
Fixed wing aircraft	1.006	0.816	1.464	0.769
Helicopters	0.934	0.424	1.288	0.712

4.3 TARGET DISTRIBUTION EFFECTS ON POD

Both the inverse cube law and random search curve assume a uniform probability distribution of target location within the search area. However, the target distribution within an actual SAR search area is quite likely not to be random; the most probable target position may well be in the center of the area with the probability of a target being at a particular location

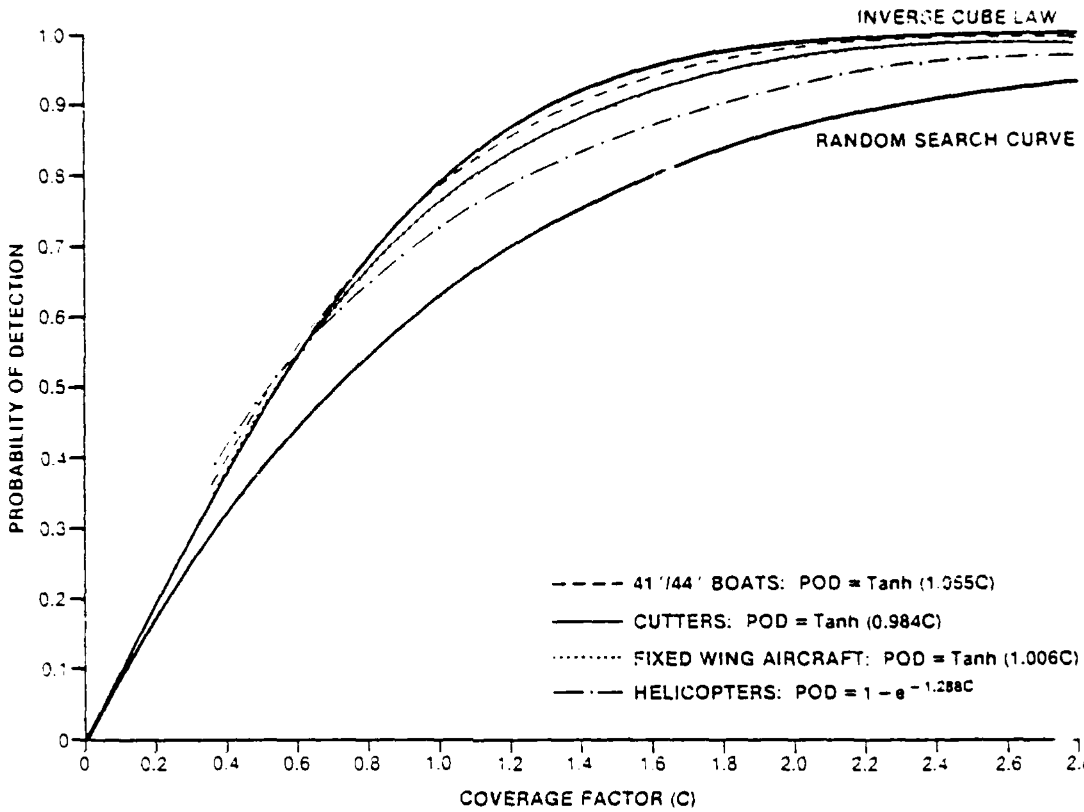


Figure 4-3. Comparison of Best-Fit POD Models for SRU Types

decreasing as the location approaches any of the search area boundaries. For the types of searches (PS or CS) conducted in these experiments, the perimeter areas (areas within S/2 of the area boundaries) are searched less thoroughly than interior areas (i.e., no overlapping of lateral range curves on adjacent search legs). For a uniform target distribution, a greater percentage of targets is in these perimeter areas than for a distribution with more targets in central areas. Therefore, the effect of a less thorough search of the perimeter areas should be greater for a uniform distribution than the distribution with more targets in the central areas.

During the first visual detection experiment (fall 1978), no attempt was made to maintain a uniform target distribution and, as a result, the target distribution was biased toward more targets in central areas (see Table 4-3).

Table 4-3. Distribution of Targets

Location Within Search Area	Percentage of Search Area*	Fall 1978 Experiment		1979 Experiments	
		Expected** Number	Actual Number	Expected** Number	Actual Number
Central areas	36 (9/25)	58 (160 X 0.36)	98	290 (806 X 0.36)	336
Corners	16 (4/25)	26 (160 X 0.16)	1	129 (806 X 0.16)	91
Borders except for corners	48 (12/25)	77 (160 X 0.48)	61	387 (806 X 0.48)	379

*All search areas were divided into 5 X 5 grids to normalize the results.

**Expected number of targets in this area if the distribution were uniform over the search area.

During the two subsequent experiments conducted in Block Island Sound (spring 1979 and fall 1979), an attempt was made to achieve a more uniform distribution (see Table 4-3). Therefore, by comparing the POD results between these experiments, the effects of target distribution on the POD model can be investigated in a cursory fashion.

The results of this comparison are shown in Figure 4-4. The best-fit curve for the 1978 data lies above that of the 1979 data. The two curves differ sufficiently to reject, at the 90-percent confidence level, the hypothesis they represent a single model fit. Thus, preliminary indications are that target distribution differences may have an effect on POD. A more rigorous investigation into detection performance for various target locations within the search area should be conducted in the future to better quantify the effect of target location on POD. Suggestions for this investigation are made in Section 4.5.

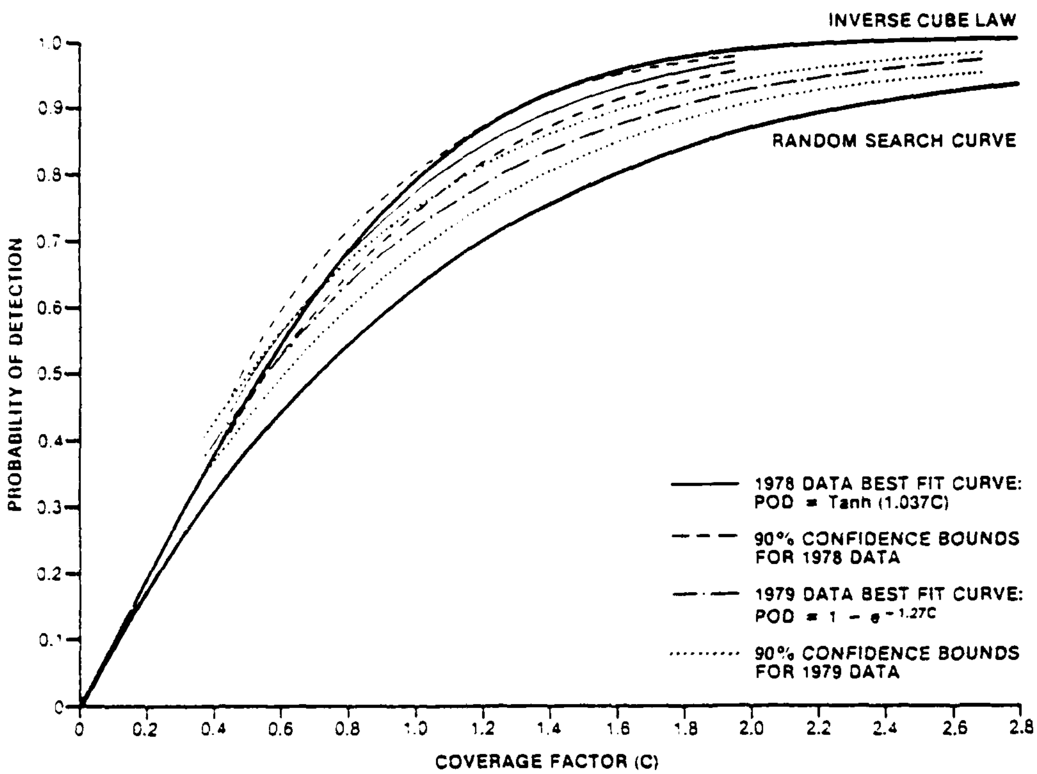


Figure 4-4. Comparison of POD Models for 1978 and 1979 Experiments

4.4 INFLUENCE OF LATERAL RANGE CURVE SHAPE ON POD MODEL

Another question of interest with respect to a POD model is its applicability over a wide range of environmental conditions, since the shape of the lateral range curves as determined from empirical results of Reference 2 changed dramatically when environmental conditions deteriorated (see Figure 4-5).

To investigate this question, the empirical data which yielded "peaked" lateral range curves (which were generally typical of good to excellent environmental conditions) were compared to data which yielded "flat" lateral range curves (typical of poor environmental conditions) (see Figure 4-5). These data were binned on C and fitted with the functions described in Section 3.3. The results with highest R^2 are shown in Figure 4-6. Note that the peaked lateral range curve yields slightly higher POD predictions than the

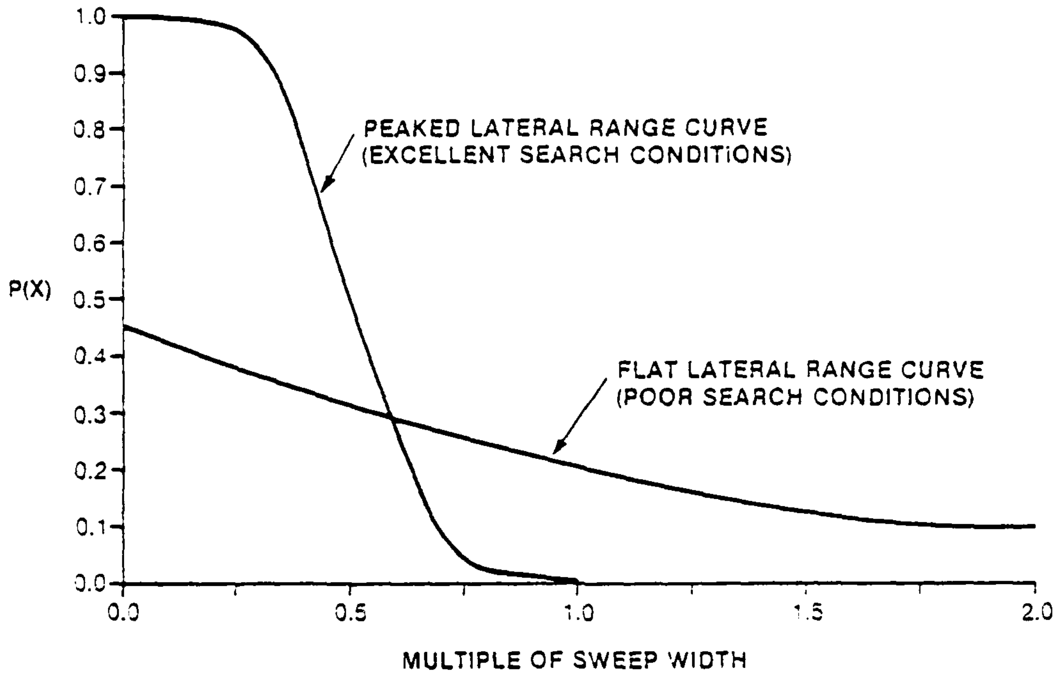


Figure 4-5. Example of Peaked and Flat Lateral Range Curves

flat lateral range curve. While the difference between the two fits is not statistically significant at the 90-percent confidence level, it suggests that further investigation into the influence of lateral range curve shape on POD should be made.

4.5 CONCLUSIONS

The following conclusions are drawn on the basis of these analyses:

a. The present SAR Manual POD versus coverage factor model overestimates POD, particularly at higher coverage factors. Other mathematical models that predict performance between that which the current POD versus C model and the random search curve predict provide much better fits to the empirical data. Therefore, there is a clear need to revise the SAR Manual POD versus C model.

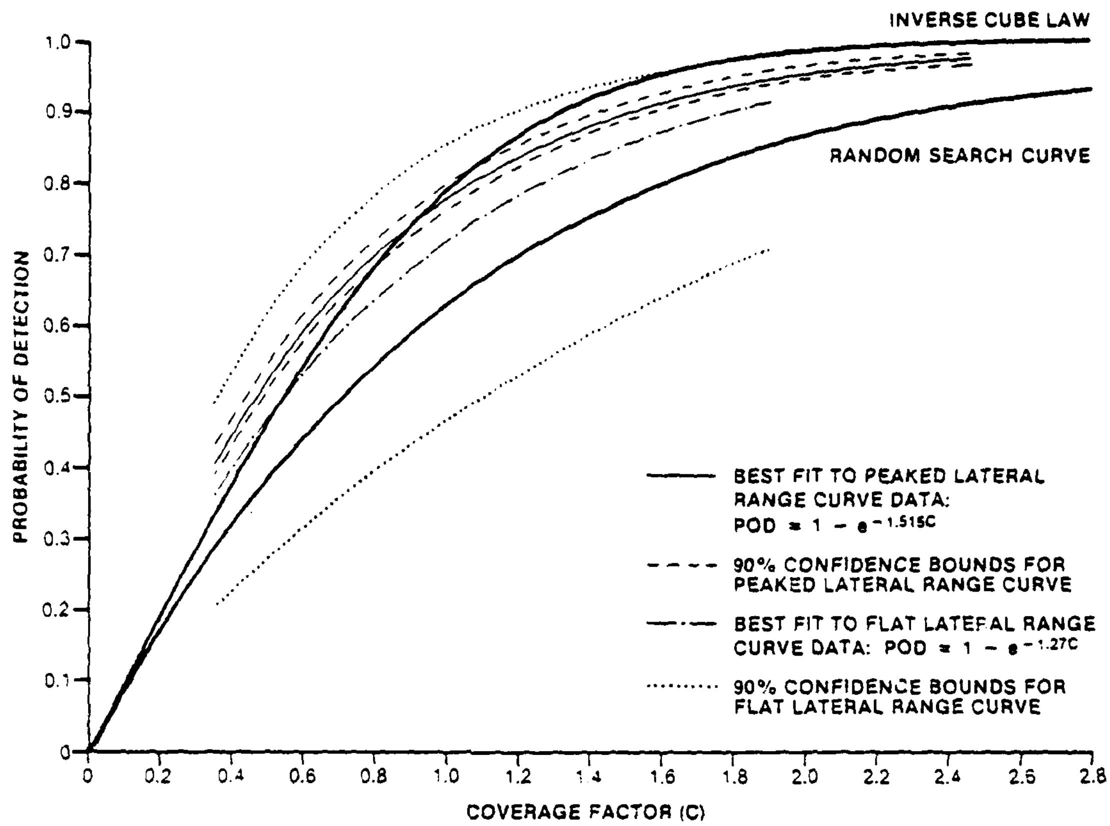


Figure 4-6. Comparison of POD for Peaked and Flat Lateral Range Curves

b. With the development of empirically derived lateral range curves, the standard method of determining POD should use these lateral range curves by "driving" them through the search area and determining the expected value of POD directly. The Computer-Assisted Search Planning (CASP) system should be used to accomplish this and a manual version of the CASP model should replace the present POD prediction method in the National SAR Manual. It is necessary that any manual "backup" POD model provide predictions consistent with the standard computerized technique.

4.6 RECOMMENDATIONS

The following recommendations are provided on the basis of these analyses:

a. For use with the CASP model, it is recommended that a method that determines POD directly from lateral range curves, navigation error distribution, and probability distribution of target location be implemented. POD predictions generated from the CASP model can then be compiled in a form suitable for manual/calculator methods.

b. Because navigation limitations are expected to influence POD, a method for quantifying these effects should be developed. This development should include:

(1) Analysis of navigation errors experienced by each SRU type during R&D Center detection experiments. This should include development of representative navigation error distributions for each SRU and navigation equipment combination.

(2) Convolution of lateral range curves with navigation error distributions through the use of either mathematical expressions or Monte Carlo computer simulation (depending upon the nature of the navigation errors). These convoluted lateral range curves would be used in the CASP POD calculation.

(3) Comparison of CASP POD predictions with empirically derived POD data to validate the CASP method.

c. Determination of POD directly from lateral range curves provides the opportunity to evaluate alternative search tactics. Using this method, the best tactic(s) for available SRU resources and a given probability distribution of target location can be determined. Therefore, further analysis should be conducted to compare empirical POD results with model predictions for targets located both between adjacent search tracks and near the search area borders (within S/2 of only one search leg). The results of this analysis should be used to establish and validate a method for treating different probability distributions of target location in the CASP model.

REFERENCES

1. U.S. Coast Guard. National Search and Rescue Manual. CG-308, Superintendent of Documents. Washington, D. C.: Government Printing Office, July 1973, with amendments 1-2.

2 Edwards, N.C.; Osmer, S. R.; Mazour, T. J.; and Hover, G. L. Analysis of Visual Detection Performance for 16-Foot Boat and Life Raft Targets. U. S. Coast Guard Research and Development Center and Analysis & Technology, Inc., February 1980.

3. Koopman, B. O. Search and Screening. U. S. Navy OEG Report No. 56. Washington, D. C., 1946.

4. U.S. Naval Academy. Naval Operations Analysis. Annapolis, Maryland: Naval Institute Press, 1968.

5. Richardson, H. R., et al. The Contribution of Operations Analysis to the 1974 Clearance of Unexploded Ordnance from the Suez Canal. Daniel H. Wagner, Associates.

Appendix A
RAW DATA

A.1 INTRODUCTION

This appendix contains raw data files compiled during the three visual detection experiments for each SRU type. Each row of data represents successes or failures on an individual search. These data were used to develop the empirical POD versus coverage factor curves presented in this report. The following is a key to the format of the raw data files:

Column 1: Search Number
Column 2: Number of targets detected or missed during the search (detection or miss indicated in column 3).
Column 3: Detection or Miss (1 = Detection 0 = Miss)
Column 4: Coverage Factor
Column 5: Target Type (1 = 16-foot Boat 2 = Raft)
Column 6: Visibility* (nautical miles)
Column 7: Wind Speed* (knots)
Column 8: Swell Height* (feet)
Column 9: SRU Type (1 = 41/44' Boats, 2 = Cutters, 3 = Fixed Wing Aircraft, 4 = Helicopters)
Column 10: Track Spacing (nautical miles)

*Time-weighted average for the search.

41'/44' BOAT SEARCHES

1	4	1	0.75	1.00	10.00	12.50	1.50	1.00	4.00
1	2	0	0.75	1.00	10.00	12.50	1.50	1.00	4.00
2	4	1	0.84	1.00	15.00	3.80	1.00	1.00	5.00
2	2	0	0.84	1.00	15.00	3.60	1.00	1.00	5.00
3	4	1	0.75	1.00	15.00	2.00	1.50	1.00	5.00
3	1	0	0.75	1.00	15.00	2.00	1.50	1.00	5.00
4	5	1	0.58	1.00	12.00	11.50	2.00	1.00	4.00
4	2	0	0.58	1.00	12.00	11.50	2.00	1.00	4.00
5	4	1	0.63	1.00	11.10	10.90	1.60	1.00	4.00
5	1	0	0.63	1.00	11.10	10.90	1.60	1.00	4.00
6	5	1	0.50	1.00	10.00	16.00	5.00	1.00	2.00
6	1	0	0.50	1.00	10.00	16.00	5.00	1.00	2.00
7	4	1	0.75	1.00	10.10	5.90	1.70	1.00	4.00
7	1	0	0.76	1.00	10.10	5.90	1.70	1.00	4.00
8	2	1	0.76	1.00	10.00	9.50	1.50	1.00	4.00
8	1	0	0.75	1.00	10.00	9.50	1.50	1.00	4.00
9	1	1	0.60	1.00	15.00	3.00	1.50	1.00	5.00
9	1	0	0.60	1.00	15.00	3.00	1.50	1.00	5.00
10	1	1	0.48	1.00	10.70	5.70	2.50	1.00	4.00
10	2	0	0.48	1.00	10.70	3.70	2.50	1.00	4.00
11	3	1	0.55	1.00	5.00	10.00	2.50	1.00	2.00
11	1	0	0.55	1.00	5.00	10.00	2.50	1.00	2.00
12	4	1	0.73	1.00	10.00	13.60	1.50	1.00	4.00
12	2	0	0.73	1.00	10.00	13.60	1.50	1.00	4.00
13	6	1	0.65	1.00	12.00	11.70	1.50	1.00	4.00
14	4	1	1.05	1.00	15.00	3.00	0.00	1.00	4.00
15	2	1	1.05	1.00	15.00	4.50	0.00	1.00	4.00
15	2	0	1.05	1.00	15.00	4.50	0.00	1.00	4.00
16	4	1	1.00	1.00	15.00	2.90	0.00	1.00	4.00
17	2	1	0.93	1.00	15.00	6.30	0.00	1.00	4.00
17	2	0	0.93	1.00	15.00	5.30	0.00	1.00	4.00
18	1	1	1.20	1.00	6.00	5.90	0.60	1.00	5.00
18	3	0	1.20	1.00	6.00	5.90	0.60	1.00	5.00
19	2	1	0.90	1.00	6.00	6.20	1.00	1.00	3.00
19	3	0	0.90	1.00	6.00	6.20	1.00	1.00	3.00
20	3	0	0.38	1.00	15.00	11.50	2.00	1.00	4.00
21	1	1	0.43	1.00	15.00	10.90	1.70	1.00	4.00
21	4	0	0.43	1.00	15.00	10.90	1.70	1.00	4.00
22	3	0	0.38	1.00	15.00	11.60	2.00	1.00	4.00
23	1	1	0.45	1.00	15.00	10.70	1.70	1.00	4.00
23	4	0	0.45	1.00	15.00	10.70	1.70	1.00	4.00
24	2	1	1.13	1.00	5.00	6.30	0.70	1.00	3.00
24	2	0	1.13	1.00	5.00	6.30	0.70	1.00	3.00
25	3	1	0.93	1.00	5.00	5.90	1.00	1.00	3.00
25	2	0	0.93	1.00	6.00	5.90	1.00	1.00	3.00
26	1	1	0.50	1.00	2.40	12.70	3.00	1.00	2.00
26	1	0	0.50	1.00	2.40	12.70	3.00	1.00	2.00
27	1	1	0.45	1.00	3.00	13.40	2.50	1.00	2.00
27	1	0	0.45	1.00	3.00	13.40	2.50	1.00	2.00
28	5	1	1.45	2.00	15.00	1.00	0.50	1.00	2.00
29	3	1	1.55	2.00	15.00	2.00	0.50	1.00	2.00
29	1	0	1.55	2.00	15.00	2.00	0.50	1.00	2.00
30	4	1	1.55	2.00	15.00	1.00	0.50	1.00	2.00
30	1	0	1.65	2.00	15.00	1.00	0.50	1.00	2.00

31	4	1	1.08	2.00	15.00	5.00	0.50	1.00	4.00
31	1	0	1.08	2.00	15.00	5.00	0.50	1.00	4.00
32	5	1	0.95	2.00	15.00	6.50	0.50	1.00	4.00
32	2	0	0.95	2.00	15.00	6.50	0.50	1.00	4.00
33	2	0	0.23	2.00	10.20	9.90	1.60	1.00	4.00
34	1	1	0.60	2.00	9.60	4.50	1.10	1.00	4.00
34	1	0	0.60	2.00	9.50	4.50	1.10	1.00	4.00
35	1	1	0.55	2.00	12.10	6.10	2.00	1.00	4.00
35	1	0	0.55	2.00	12.10	6.10	2.00	1.00	4.00
36	3	1	0.95	2.00	15.00	4.50	0.50	1.00	4.00
36	2	0	0.95	2.00	15.00	4.50	0.50	1.00	4.00
37	2	1	0.65	2.00	15.00	5.60	0.50	1.00	4.00
37	3	0	0.65	2.00	15.00	5.60	0.50	1.00	4.00
38	5	1	0.60	2.00	11.20	3.60	1.00	1.00	4.00
38	1	0	0.60	2.00	11.20	3.60	1.00	1.00	4.00
39	4	1	0.48	2.00	10.00	7.40	1.50	1.00	4.00
39	2	0	0.48	2.00	10.00	7.40	1.50	1.00	4.00
40	2	1	0.65	2.00	12.00	3.00	1.00	1.00	4.00
40	4	0	0.65	2.00	12.00	3.00	1.00	1.00	4.00
41	3	1	0.50	2.00	10.00	5.90	1.50	1.00	4.00
41	3	0	0.50	2.00	10.00	5.90	1.50	1.00	4.00
42	2	1	1.10	2.00	15.00	3.00	0.50	1.00	4.00
42	1	0	1.10	2.00	15.00	3.00	0.50	1.00	4.00
43	1	1	0.63	2.00	10.00	4.00	0.50	1.00	4.00
43	2	0	0.63	2.00	10.00	4.00	0.50	1.00	4.00
44	2	1	1.10	2.00	15.00	3.00	0.50	1.00	4.00
44	1	0	1.10	2.00	15.00	3.00	0.50	1.00	4.00
45	1	1	0.70	2.00	10.90	3.60	0.50	1.00	4.00
45	2	0	0.70	2.00	10.90	3.60	0.50	1.00	4.00
46	2	1	1.03	1.00	15.00	2.10	0.50	1.00	4.00
46	1	0	1.03	1.00	15.00	2.10	0.50	1.00	4.00
47	4	1	0.65	1.00	15.00	7.70	0.50	1.00	4.00
47	2	0	0.65	1.00	15.00	7.70	0.50	1.00	4.00
48	3	1	1.05	1.00	15.00	2.00	0.50	1.00	4.00
48	1	0	1.06	1.00	15.00	2.00	0.50	1.00	4.00
49	5	1	0.90	1.00	15.00	6.60	0.50	1.00	4.00
49	5	0	0.90	1.00	15.00	6.60	0.50	1.00	4.00
50	1	0	0.55	1.00	15.00	16.00	3.50	1.00	2.00
51	2	1	0.57	1.00	5.20	7.50	2.90	1.00	3.00
51	2	0	0.57	1.00	5.20	7.50	2.90	1.00	3.00
52	1	1	1.17	2.00	15.80	3.10	0.50	1.00	3.00
52	1	0	1.17	2.00	15.60	6.10	0.50	1.00	3.00
53	3	1	0.60	2.00	15.30	9.70	0.60	1.00	3.00
53	2	0	0.60	2.00	15.30	9.70	0.60	1.00	3.00
54	1	1	0.90	2.00	15.50	3.70	0.70	1.00	3.00
54	1	0	0.90	2.00	15.50	8.70	0.70	1.00	3.00
55	1	1	0.60	2.00	3.60	4.40	1.00	1.00	2.00
56	2	1	0.40	2.00	5.70	9.00	0.70	1.00	2.00
57	3	1	1.75	2.00	15.00	3.00	1.00	1.00	2.00
58	5	1	1.75	2.00	15.00	1.70	0.70	1.00	2.00
59	2	1	1.15	2.00	15.90	10.30	1.00	1.00	2.00
60	1	1	0.60	2.00	15.00	14.60	1.70	1.00	2.00
60	2	0	0.60	2.00	15.00	14.60	1.70	1.00	2.00
61	2	1	1.55	2.00	15.00	6.20	0.50	1.00	2.00
62	1	1	0.40	2.00	6.00	4.60	0.50	1.00	4.00

CUTTER SEARCHED

1	2	1	0.83	1.00	20.00	15.00	5.00	2.00	5.00
1	1	0	0.83	1.00	20.00	15.00	3.00	2.00	5.00
2	4	1	0.95	1.00	12.00	10.90	2.00	2.00	4.00
2	1	0	0.96	1.00	12.00	10.90	2.00	2.00	4.00
3	5	1	1.15	1.00	10.00	5.20	1.50	2.00	4.00
4	3	1	0.95	1.00	10.50	3.60	2.60	2.00	5.70
4	1	0	0.95	1.00	10.60	3.50	2.60	2.00	3.70
5	2	0	0.77	1.00	20.00	15.00	3.00	2.00	3.00
6	3	1	1.03	1.00	20.00	6.00	2.00	2.00	3.00
7	5	1	1.13	1.00	10.00	9.70	1.50	2.00	4.00
7	1	0	1.13	1.00	10.00	9.70	1.50	2.00	4.00
8	3	1	0.93	1.00	10.00	13.20	1.50	2.00	4.00
8	3	0	0.93	1.00	10.00	13.20	1.50	2.00	4.00
9	1	1	1.10	1.00	10.00	11.00	1.50	2.00	4.00
9	1	0	1.10	1.00	10.00	11.00	1.50	2.00	4.00
10	3	1	1.04	1.00	15.00	3.00	1.50	2.00	5.00
10	2	0	1.04	1.00	15.00	3.00	1.50	2.00	5.00
11	4	1	1.15	1.00	10.00	6.00	1.50	2.00	4.00
11	1	0	1.15	1.00	10.00	6.00	1.50	2.00	4.00
12	4	1	1.00	1.00	10.00	17.00	3.00	2.00	2.00
13	2	1	0.95	1.00	4.00	7.00	1.50	2.00	4.00
13	1	0	0.95	1.00	4.00	7.00	1.50	2.00	4.00
14	1	1	0.70	1.00	10.00	9.00	2.00	2.00	4.00
14	3	0	0.70	1.00	10.00	9.00	2.00	2.00	4.00
15	4	1	1.38	1.00	15.00	1.60	0.00	2.00	4.00
16	3	1	1.30	1.00	15.00	3.10	0.00	2.00	4.00
16	1	0	1.30	1.00	15.00	3.10	0.00	2.00	4.00
17	4	1	1.35	1.00	15.00	2.90	0.00	2.00	4.00
18	3	1	1.50	1.00	15.00	5.00	0.00	2.00	4.00
18	1	0	1.50	1.00	15.00	5.00	0.00	2.00	4.00
19	3	1	1.53	1.00	5.00	5.20	0.70	2.00	3.00
19	1	0	1.53	1.00	5.00	5.20	0.70	2.00	3.00
20	5	1	1.27	1.00	6.00	6.10	1.00	2.00	3.00
21	2	1	1.47	1.00	6.00	6.40	0.60	2.00	3.00
21	2	0	1.47	1.00	6.00	5.40	0.60	2.00	3.00
22	3	1	1.10	1.00	6.40	6.10	1.00	2.00	3.00
22	3	0	1.10	1.00	6.40	6.10	1.00	2.00	3.00
23	2	1	0.63	1.00	15.00	12.40	2.00	2.00	4.00
23	1	0	0.63	1.00	15.00	12.40	2.00	2.00	4.00
24	1	1	0.60	1.00	15.00	9.70	1.50	2.00	4.00
25	3	1	0.63	1.00	15.00	11.60	2.00	2.00	4.00
26	5	1	0.65	1.00	15.00	12.00	1.90	2.00	4.00
26	1	0	0.65	1.00	15.00	12.00	1.90	2.00	4.00
27	1	1	0.55	1.00	2.10	13.10	3.00	2.00	2.00
27	1	0	0.55	1.00	2.10	13.10	3.00	2.00	2.00
28	2	1	0.50	1.00	3.00	13.40	2.60	2.00	2.00
29	2	1	0.55	1.00	2.50	12.90	3.00	2.00	2.00
30	1	1	0.55	1.00	4.50	13.50	2.50	2.00	2.00
30	1	0	0.55	1.00	4.60	13.50	2.50	2.00	2.00
31	5	1	2.65	2.00	15.00	1.70	0.70	2.00	2.00
32	5	1	2.55	2.00	15.00	1.00	0.50	2.00	2.00
33	4	1	2.55	2.00	15.00	1.50	0.50	2.00	2.00
33	1	0	2.55	2.00	15.00	1.60	0.60	2.00	2.00
34	5	1	2.50	2.00	15.00	1.00	0.50	2.00	2.00

35	5	1	1.56	2.00	15.00	6.40	0.50	2.00	4.00
36	3	1	1.58	2.00	15.00	5.00	0.50	2.00	4.00
37	4	1	1.46	2.00	15.00	4.00	0.50	2.00	4.00
38	5	1	1.55	2.00	15.00	5.60	0.50	2.00	4.00
39	1	1	1.00	2.00	10.40	5.60	1.00	2.00	4.00
39	1	0	1.00	2.00	10.40	5.60	1.00	2.00	4.00
40	2	1	0.75	2.00	11.60	7.10	1.90	2.00	4.00
41	2	1	1.03	2.00	9.50	4.00	1.00	2.00	4.00
42	1	1	0.70	2.00	11.30	7.40	2.00	2.00	4.00
42	1	0	0.70	2.00	11.30	7.40	2.00	2.00	4.00
43	1	1	0.63	2.00	2.50	6.50	0.50	2.00	3.00
43	2	0	0.63	2.00	2.50	6.50	0.50	2.00	3.00
44	2	0	0.43	2.00	3.00	6.30	0.50	2.00	3.00
45	1	1	0.63	2.00	3.00	7.00	0.50	2.00	3.00
45	2	0	0.65	2.00	3.00	7.00	0.50	2.00	3.00
46	2	0	0.43	2.00	2.90	6.60	0.50	2.00	3.00
47	6	1	0.63	2.00	11.70	3.30	1.00	2.00	4.00
48	5	1	0.85	2.00	10.00	6.20	1.40	2.00	4.00
48	1	0	0.85	2.00	10.00	6.20	1.40	2.00	4.00
49	6	1	1.25	2.00	12.00	3.00	1.00	2.00	4.00
50	6	1	1.00	2.00	10.50	4.50	1.10	2.00	4.00
51	3	1	1.48	2.00	15.00	3.00	0.50	2.00	4.00
52	2	1	1.10	2.00	11.50	3.70	0.50	2.00	4.00
52	1	0	1.10	2.00	11.50	3.70	0.50	2.00	4.00
53	3	1	1.48	2.00	15.00	3.00	0.50	2.00	4.00
54	3	1	1.05	2.00	11.20	3.80	0.50	2.00	4.00
55	3	1	1.05	1.00	15.00	11.90	0.90	2.00	4.00
55	1	0	1.05	1.00	15.00	11.90	0.90	2.00	4.00
56	3	1	1.33	1.00	15.00	2.00	0.50	2.00	4.00
57	5	1	1.08	1.00	15.00	8.60	0.50	2.00	4.00
58	2	0	1.45	1.00	15.00	15.00	1.00	2.00	2.00
59	1	1	0.70	1.00	15.00	19.00	3.20	2.00	2.00
60	3	1	0.93	1.00	4.70	8.80	3.00	2.00	3.00
60	1	0	0.93	1.00	4.70	8.80	3.00	2.00	3.00
61	1	1	0.97	1.00	6.00	6.00	2.00	2.00	3.00
61	2	0	0.97	1.00	6.00	6.00	2.00	2.00	3.00
62	1	1	1.57	2.00	14.80	7.50	0.50	2.00	3.00
62	1	0	1.57	2.00	14.80	7.50	0.50	2.00	3.00
63	3	1	0.93	2.00	15.00	10.00	1.00	2.00	4.00
63	2	0	0.93	2.00	15.00	10.00	1.00	2.00	4.00
64	2	1	1.50	2.00	16.20	9.30	0.60	2.00	3.00
64	1	0	1.50	2.00	16.20	9.30	0.60	2.00	3.00
65	2	1	0.78	2.00	14.10	11.30	1.00	2.00	4.00
65	3	0	0.78	2.00	14.10	11.30	1.00	2.00	4.00
66	1	1	1.05	2.00	4.70	6.30	0.60	2.00	2.00
66	1	0	1.05	2.00	4.70	6.30	0.80	2.00	2.00
67	1	1	0.73	2.00	8.00	4.90	0.50	2.00	2.00
68	1	1	1.20	2.00	4.10	4.80	0.60	2.00	2.00
69	1	1	0.75	2.00	5.90	10.70	0.80	2.00	2.00
70	1	1	1.25	2.00	13.70	10.40	1.00	2.00	2.00
71	1	1	0.70	2.00	15.00	15.30	1.00	2.00	4.00
71	1	0	0.70	2.00	15.00	15.30	1.00	2.00	4.00
72	3	1	2.60	2.00	15.00	3.00	1.00	2.00	2.00
73	5	1	2.40	2.00	15.00	2.20	0.60	2.00	2.00
74	4	1	1.77	2.00	15.00	6.20	0.50	2.00	3.00

FIXED WING SEARCHES

1	4	1	1.35	1.00	10.00	10.00	1.00	3.00	2.00
2	3	1	1.10	1.00	13.00	11.00	1.00	3.00	2.00
2	1	0	1.10	1.00	13.00	11.00	1.00	3.00	2.00
3	2	1	0.95	1.00	15.00	4.00	1.00	3.00	4.00
4	4	1	1.23	1.00	15.00	9.00	1.00	3.00	3.00
5	4	1	1.13	1.00	15.00	9.00	1.00	3.00	3.00
6	2	1	1.03	1.00	15.00	10.00	1.00	3.00	3.00
7	2	0	0.90	1.00	15.00	9.00	1.00	3.00	3.00
8	4	1	1.23	1.00	15.00	9.00	1.00	3.00	3.00
9	3	1	1.10	1.00	15.00	9.40	1.00	3.00	3.00
9	1	0	1.10	1.00	15.00	9.40	1.00	3.00	3.00
10	3	1	1.00	1.00	15.00	9.00	1.00	3.00	3.00
11	3	1	1.07	1.00	15.00	7.50	1.00	3.00	3.00
11	1	0	1.07	1.00	15.00	7.50	1.00	3.00	3.00
12	3	1	0.58	1.00	4.10	4.90	0.00	3.00	4.00
12	1	0	0.58	1.00	4.10	4.90	0.00	3.00	4.00
13	2	1	0.45	1.00	3.50	6.00	0.00	3.00	4.00
13	2	0	0.45	1.00	3.50	6.00	0.00	3.00	4.00
14	2	1	1.15	1.00	3.40	3.70	0.00	3.00	2.00
14	1	0	1.15	1.00	3.40	3.70	0.00	3.00	2.00
15	3	1	1.00	1.00	3.00	3.20	0.00	3.00	2.00
15	1	0	1.00	1.00	3.00	3.20	0.00	3.00	2.00
16	2	1	1.53	1.00	15.00	4.00	5.00	3.00	3.00
17	1	1	1.53	1.00	15.00	6.20	0.50	3.00	3.00
17	1	0	1.53	1.00	15.00	6.20	0.50	3.00	3.00
18	1	0	0.78	1.00	15.00	11.50	0.50	3.00	4.00
19	3	1	1.25	1.00	4.50	4.00	0.00	3.00	2.00
20	2	1	1.15	1.00	4.50	4.00	0.00	3.00	2.00
20	1	0	1.15	1.00	4.50	4.00	0.00	3.00	2.00
21	3	1	0.60	1.00	4.00	4.00	0.00	3.00	4.00
21	1	0	0.60	1.00	4.00	4.00	0.00	3.00	4.00
22	1	1	0.53	1.00	4.00	4.00	0.00	3.00	4.00
22	3	0	0.53	1.00	4.00	4.00	0.00	3.00	4.00
23	4	1	1.60	1.00	15.00	10.40	0.70	3.00	2.00
24	2	1	1.30	1.00	15.00	13.00	1.50	3.00	2.00
24	2	0	1.30	1.00	15.00	13.00	1.50	3.00	2.00
25	3	1	1.55	1.00	15.00	11.00	2.30	3.00	2.00
25	1	0	1.55	1.00	15.00	11.00	2.30	3.00	2.00
26	2	0	1.20	1.00	15.00	4.00	0.50	3.00	4.00
27	1	1	1.15	1.00	15.00	4.00	0.50	3.00	4.00
27	1	0	1.15	1.00	15.00	4.00	0.50	3.00	4.00
28	1	1	1.35	1.00	15.00	15.00	1.00	3.00	2.00
29	1	0	1.35	1.00	15.00	12.00	1.00	3.00	2.00
30	1	1	1.05	1.00	15.00	6.80	0.50	3.00	4.00
30	1	0	1.05	1.00	15.00	6.80	0.50	3.00	4.00
31	1	1	0.83	1.00	15.00	10.00	0.50	3.00	4.00
31	1	0	0.83	1.00	15.00	10.00	0.50	3.00	4.00
32	2	1	1.60	1.00	15.00	11.30	1.00	3.00	2.00
33	1	1	1.50	1.00	14.90	10.10	1.00	3.00	2.00
33	1	0	1.50	1.00	14.90	10.10	1.00	3.00	2.00
34	3	1	0.83	2.00	15.00	5.50	0.50	3.00	4.00
35	3	1	0.50	2.00	15.00	7.30	0.50	3.00	4.00
36	3	1	0.53	2.00	15.00	4.50	0.50	3.00	4.00
37	1	1	0.33	2.00	15.00	5.50	0.80	3.00	4.00

37	1	0	0.63	2.00	15.00	5.60	0.60	3.00	4.00
38	2	1	0.60	2.00	7.00	7.60	0.90	3.00	4.00
38	1	0	0.60	2.00	7.00	7.60	0.90	3.00	4.00
39	3	1	0.58	2.00	7.00	7.50	1.00	3.00	4.00
40	2	1	0.75	2.00	3.80	5.70	3.00	3.00	2.00
40	1	0	0.75	2.00	3.80	5.70	3.00	3.00	2.00
41	3	1	0.90	2.00	6.00	5.90	2.60	3.00	2.00
42	1	1	1.60	2.00	6.00	4.50	0.50	3.00	2.00
43	2	1	1.23	2.00	15.00	3.00	0.00	3.00	3.00
43	1	0	1.23	2.00	15.00	3.00	0.00	3.00	3.00
44	3	1	1.23	2.00	15.00	3.00	0.00	3.00	3.00
45	2	1	1.07	2.00	15.00	7.00	0.50	3.00	3.00
46	2	1	1.03	2.00	15.00	7.60	0.50	3.00	3.00
46	1	0	1.03	2.00	15.00	7.60	0.50	3.00	3.00
47	2	1	1.00	1.00	15.00	18.00	2.00	3.00	2.00
48	1	1	0.65	1.00	15.00	21.60	2.00	3.00	2.00
48	1	0	0.65	1.00	15.00	21.60	2.00	3.00	2.00
49	1	1	0.95	1.00	15.00	17.00	2.90	3.00	2.00
49	1	0	0.95	1.00	15.00	17.00	2.90	3.00	2.00
50	1	1	0.65	1.00	15.00	21.30	3.50	3.00	2.00
51	2	1	1.15	1.00	15.00	12.00	2.00	3.00	2.00
52	2	1	1.70	1.00	15.00	4.00	1.00	3.00	2.00
53	3	0	1.50	1.00	15.00	7.00	1.00	3.00	2.00
54	2	1	1.20	1.00	13.10	6.90	1.90	3.00	2.00
54	1	0	1.20	1.00	13.10	6.90	1.90	3.00	2.00
55	2	1	0.77	2.00	10.00	13.00	1.00	3.00	3.00
55	1	0	0.77	2.00	10.00	13.00	1.00	3.00	3.00
56	1	0	0.77	2.00	10.00	5.00	1.00	3.00	3.00
57	2	1	0.80	2.00	10.00	9.70	1.00	3.00	3.00
58	1	1	0.67	2.00	10.00	15.00	1.00	3.00	3.00
58	1	0	0.67	2.00	10.00	15.00	1.00	3.00	3.00
59	2	1	0.77	2.00	6.20	8.60	1.00	3.00	3.00
60	1	1	0.67	2.00	9.00	8.00	1.00	3.00	3.00
60	1	0	0.67	2.00	9.00	8.00	1.00	3.00	3.00
61	1	1	0.83	2.00	10.00	8.70	1.00	3.00	3.00
61	1	0	0.83	2.00	10.00	8.70	1.00	3.00	3.00
62	1	1	0.80	2.00	10.00	10.00	1.00	3.00	3.00
62	1	0	0.80	2.00	10.00	10.00	1.00	3.00	3.00
63	1	1	0.95	2.00	15.00	20.00	1.00	3.00	2.00
63	1	0	0.95	2.00	15.00	20.00	1.00	3.00	2.00
64	1	1	0.45	2.00	15.00	21.60	3.90	3.00	2.00
64	1	0	0.45	2.00	15.00	21.60	3.90	3.00	2.00
65	1	1	0.75	2.00	15.00	16.20	2.00	3.00	2.00
65	1	0	0.75	2.00	15.00	16.20	2.00	3.00	2.00
66	1	0	0.40	2.00	15.00	20.30	3.20	3.00	2.00
67	3	1	1.30	2.00	15.00	1.00	0.50	3.00	3.00
68	3	1	1.30	2.00	15.00	1.00	0.50	3.00	3.00
69	1	1	1.23	2.00	15.00	7.00	0.50	3.00	3.00
69	1	0	1.23	2.00	15.00	7.00	0.50	3.00	3.00
70	1	1	1.00	2.00	15.00	9.90	1.50	3.00	3.00
70	2	0	1.00	2.00	15.00	9.90	1.50	3.00	3.00
71	2	1	1.10	2.00	12.00	15.00	2.00	3.00	2.00
72	2	1	1.15	2.00	12.60	14.20	2.00	3.00	2.00
73	1	1	1.00	2.00	14.00	13.90	3.00	3.00	2.00

73	1	0	1.00	2.00	14.00	15.90	5.00	5.00	2.00
74	2	1	1.05	2.00	14.00	15.50	5.00	5.00	2.00
75	2	1	1.15	2.00	15.00	15.40	1.50	5.00	2.00
76	1	1	0.80	2.00	15.00	16.90	2.80	5.00	2.00
76	1	0	0.60	2.00	15.00	16.90	2.60	5.00	2.00
77	2	0	0.55	2.00	15.00	20.50	5.50	5.00	2.00
78	2	1	1.05	2.00	9.20	9.70	1.00	5.00	2.00
79	2	0	1.15	2.00	7.50	8.00	1.00	5.00	2.00
80	5	1	1.40	2.00	5.00	4.00	0.50	5.00	2.00
81	2	1	1.35	2.00	5.00	4.00	0.50	5.00	2.00
82	2	0	1.15	2.00	15.00	14.00	2.00	5.00	2.00
83	2	1	1.05	2.00	15.00	14.80	2.40	5.00	2.00
84	2	1	1.00	2.00	14.00	14.80	5.00	5.00	2.00
85	1	1	1.05	2.00	14.00	15.00	5.00	5.00	2.00
85	1	0	1.05	2.00	14.00	15.00	5.00	5.00	2.00
86	5	1	0.90	2.00	15.00	9.00	1.00	5.00	5.00
[illegible]	2	1	0.90	2.00	15.00	10.00	1.00	5.00	5.00

HELO SEARCHED

1	2	1	0.74	1.00	11.20	9.10	2.00	4.00	5.00
1	1	0	0.74	1.00	11.20	9.10	2.00	4.00	5.00
2	1	1	0.42	1.00	11.00	13.00	2.00	4.00	5.00
2	2	0	0.42	1.00	11.00	13.00	2.00	4.00	5.00
3	3	1	1.95	1.00	4.00	9.50	1.50	4.00	2.00
4	2	1	1.30	1.00	6.00	11.80	3.00	4.00	2.00
4	1	0	1.30	1.00	6.00	11.80	3.00	4.00	2.00
5	2	1	1.73	1.00	15.00	2.00	2.50	4.00	4.00
6	1	1	1.43	1.00	15.00	4.50	1.00	4.00	4.00
6	1	0	1.43	1.00	15.00	4.50	1.00	4.00	4.00
7	1	1	0.60	1.00	25.00	15.00	2.00	4.00	6.00
7	1	0	0.60	1.00	25.00	15.00	2.00	4.00	6.00
8	2	1	0.55	1.00	25.00	15.00	2.00	4.00	6.00
9	2	1	0.84	1.00	6.00	15.00	2.10	4.00	2.50
9	1	0	0.84	1.00	6.00	15.00	2.10	4.00	2.50
10	1	1	0.66	1.00	6.00	11.50	1.60	4.00	5.00
10	1	0	0.66	1.00	6.00	11.50	1.60	4.00	5.00
11	1	1	0.86	1.00	10.00	8.70	1.00	4.00	5.00
11	2	0	0.88	1.00	10.00	6.70	1.00	4.00	5.00
12	1	1	1.24	1.00	15.00	3.00	1.00	4.00	5.00
12	1	0	1.24	1.00	15.00	3.00	1.00	4.00	5.00
13	2	1	1.22	1.00	15.00	5.00	1.50	4.00	5.00
13	1	0	1.22	1.00	15.00	5.00	1.50	4.00	5.00
14	3	1	1.36	1.00	15.00	2.10	1.00	4.00	5.00
15	3	1	1.34	1.00	15.00	1.00	1.00	4.00	5.00
16	1	1	0.59	1.00	25.00	15.00	2.00	4.00	6.20
17	1	1	1.31	1.00	5.00	5.00	0.50	4.00	2.60
18	1	1	1.64	1.00	6.00	5.00	0.50	4.00	2.50
19	1	1	0.70	1.00	6.00	7.00	1.50	4.00	5.00
20	2	1	0.90	1.00	10.00	10.00	1.00	4.00	4.00
20	1	0	0.90	1.00	10.00	10.00	1.00	4.00	4.00
21	2	1	0.83	1.00	10.00	10.00	1.00	4.00	4.00
21	1	0	0.83	1.00	10.00	10.00	1.00	4.00	4.00
22	1	1	1.00	1.00	15.00	6.00	2.00	4.00	4.00
22	3	0	1.00	1.00	15.00	6.00	2.00	4.00	4.00
23	2	0	1.18	1.00	15.00	4.00	1.00	4.00	4.00
24	3	1	2.00	1.00	15.00	9.00	1.00	4.00	2.50
25	2	1	1.24	1.00	15.00	10.00	1.00	4.00	2.50
25	1	0	1.24	1.00	15.00	10.00	1.00	4.00	2.50
26	1	1	1.40	1.00	15.00	9.30	1.00	4.00	5.00
26	2	0	1.40	1.00	15.00	9.30	1.00	4.00	5.00
27	2	1	2.13	1.00	15.00	3.50	0.00	4.00	5.00
28	2	1	1.97	1.00	15.00	4.00	0.00	4.00	5.00
29	2	1	1.25	1.00	15.00	6.50	0.50	4.00	4.00
30	1	1	1.00	1.00	15.00	11.00	0.50	4.00	4.00
30	1	0	1.00	1.00	15.00	11.00	0.50	4.00	4.00
31	2	1	0.56	1.00	3.50	6.00	0.00	4.00	6.00
31	2	0	0.56	1.00	3.50	6.00	0.00	4.00	6.00
32	3	1	1.00	1.00	3.70	5.40	0.00	4.00	6.00
32	1	0	1.00	1.00	3.70	5.40	0.00	4.00	6.00
33	2	1	1.28	1.00	3.00	3.50	0.00	4.00	6.00
33	1	0	1.28	1.00	3.00	3.50	0.00	4.00	6.00
34	1	1	0.56	1.00	3.00	3.20	0.00	4.00	6.00
34	3	0	0.56	1.00	3.00	3.20	0.00	4.00	6.00

35	2	1	1.50	1.00	15.00	10.90	1.50	4.00	6.00
35	1	0	1.50	1.00	15.00	10.90	1.50	4.00	5.00
36	3	1	1.25	1.00	15.00	13.90	1.70	4.00	6.00
37	2	1	1.50	1.00	15.00	11.00	2.00	4.00	5.00
38	2	1	1.52	1.00	15.00	11.00	2.10	4.00	5.00
38	1	0	1.52	1.00	15.00	11.00	2.10	4.00	6.00
39	3	1	1.05	1.00	15.00	11.00	1.00	4.00	4.00
39	1	0	1.05	1.00	15.00	11.00	1.00	4.00	4.00
40	3	1	1.00	1.00	15.00	11.00	1.00	4.00	4.00
40	1	0	1.00	1.00	15.00	11.00	1.00	4.00	4.00
41	2	1	2.00	1.00	15.00	13.00	1.50	4.00	2.00
41	1	0	2.00	1.00	15.00	13.00	1.50	4.00	2.00
42	1	1	1.05	1.00	15.00	14.00	2.00	4.00	2.00
42	3	0	1.05	1.00	15.00	14.00	2.00	4.00	2.00
43	4	1	0.88	1.00	15.00	11.00	1.00	4.00	5.00
44	1	1	0.88	1.00	15.00	8.00	2.00	4.00	5.00
44	2	0	0.88	1.00	15.00	8.00	2.00	4.00	5.00
45	2	1	1.25	1.00	15.00	4.00	0.50	4.00	5.00
46	2	1	1.14	1.00	15.00	4.70	0.50	4.00	5.00
47	2	1	1.08	1.00	15.00	6.00	0.50	4.00	5.00
48	2	1	0.94	1.00	15.00	7.50	0.50	4.00	5.00
49	1	1	0.96	1.00	15.00	10.00	0.50	4.00	5.00
49	1	0	0.96	1.00	15.00	10.00	0.50	4.00	5.00
50	1	1	0.54	1.00	15.00	15.00	0.50	4.00	5.00
50	1	0	0.64	1.00	15.00	15.00	0.50	4.00	5.00
51	2	0	1.78	1.00	15.00	12.10	1.00	4.00	2.50
52	2	0	1.55	1.00	15.00	10.30	1.00	4.00	2.50
53	2	1	0.58	2.00	15.00	4.50	0.50	4.00	5.00
53	1	0	0.58	2.00	15.00	4.50	0.50	4.00	5.00
54	3	1	0.66	2.00	15.00	5.40	0.50	4.00	5.00
55	1	1	0.66	2.00	15.00	5.50	0.50	4.00	5.00
55	1	0	0.66	2.00	15.00	5.50	0.50	4.00	5.00
56	1	1	0.66	2.00	15.00	4.50	0.50	4.00	5.00
56	2	0	0.66	2.00	15.00	4.50	0.50	4.00	5.00
57	3	1	0.76	2.00	15.00	8.50	0.50	4.00	4.00
58	2	1	0.83	2.00	15.00	6.10	0.50	4.00	4.00
58	1	0	0.83	2.00	15.00	6.10	0.50	4.00	4.00
59	2	1	0.80	2.00	15.00	9.00	0.50	4.00	4.00
59	1	0	0.80	2.00	15.00	9.00	0.50	4.00	4.00
60	3	1	0.66	2.00	15.00	11.00	1.00	4.00	4.00
61	1	1	0.46	2.00	5.50	7.20	1.00	4.00	5.00
61	2	0	0.46	2.00	6.50	7.20	1.00	4.00	5.00
62	2	1	0.44	2.00	5.00	8.00	1.00	4.00	5.00
62	1	0	0.44	2.00	5.00	8.00	1.00	4.00	5.00
63	2	1	0.36	2.00	7.20	12.20	1.00	4.00	5.00
64	2	1	0.28	2.00	6.00	13.00	2.50	4.00	5.00
64	1	0	0.28	2.00	6.00	13.00	2.50	4.00	5.00
65	1	1	0.70	2.00	15.00	3.00	0.00	4.00	5.00
65	1	0	0.70	2.00	15.00	3.00	0.00	4.00	5.00
66	2	1	0.54	2.00	15.00	6.00	0.00	4.00	5.00
67	2	1	1.03	2.00	15.00	7.80	0.50	4.00	3.00
67	1	0	1.03	2.00	15.00	7.80	0.50	4.00	3.00
68	2	1	1.03	2.00	15.00	8.00	0.50	4.00	3.00
68	1	0	1.03	2.00	15.00	8.00	0.50	4.00	3.00
69	1	1	0.50	2.00	1.00	5.00	3.00	4.00	2.50

69	1	0	0.57	2.00	1.00	5.00	3.00	4.00	2.50
70	1	1	0.56	2.00	1.00	5.00	3.00	4.00	2.50
70	1	0	0.55	2.00	1.00	5.00	3.00	4.00	2.50
71	4	1	1.12	2.00	9.60	5.50	1.10	4.00	2.50
72	2	1	0.54	2.00	10.00	5.50	1.00	4.00	3.00
73	2	1	1.03	1.00	15.00	12.00	2.00	4.00	3.00
74	2	1	1.40	1.00	15.00	5.20	1.20	4.00	3.00
75	3	1	1.27	1.00	15.00	7.20	1.10	4.00	3.00
76	2	1	1.00	1.00	13.50	6.70	1.90	4.00	3.00
77	2	1	0.90	2.00	10.00	9.00	1.00	4.00	3.00
77	1	0	0.90	2.00	10.00	9.00	1.00	4.00	3.00
78	1	0	0.77	2.00	10.00	5.90	1.00	4.00	3.00
79	1	1	0.67	2.00	9.60	13.60	1.00	4.00	3.00
79	1	0	0.67	2.00	9.60	13.60	1.00	4.00	3.00
80	1	1	0.73	2.00	9.00	11.00	1.00	4.00	3.00
80	1	0	0.73	2.00	9.00	11.00	1.00	4.00	3.00
81	1	0	0.87	2.00	6.00	11.00	1.00	4.00	3.00
82	1	1	0.73	2.00	6.00	10.70	1.00	4.00	3.00
82	1	0	0.73	2.00	6.00	10.70	1.00	4.00	3.00
83	1	1	0.77	2.00	10.00	10.30	1.00	4.00	3.00
83	1	0	0.77	2.00	10.00	10.30	1.00	4.00	3.00
84	1	0	1.00	2.00	10.00	8.00	1.00	4.00	3.00
85	3	1	0.97	2.00	15.00	7.40	0.60	4.00	3.00
86	2	1	0.93	2.00	15.00	9.00	1.00	4.00	3.00
87	2	1	0.97	2.00	15.00	7.90	1.00	4.00	3.00
88	2	1	1.10	2.00	15.00	8.40	1.00	4.00	3.00
89	2	1	0.66	2.00	6.90	6.60	1.00	4.00	2.50
90	1	1	0.92	2.00	7.40	7.90	1.00	4.00	2.50
90	1	0	0.92	2.00	7.40	7.90	1.00	4.00	2.50
91	1	0	1.24	2.00	5.00	4.00	0.50	4.00	2.50
92	1	1	1.24	2.00	5.20	4.70	0.50	4.00	2.50
93	1	1	0.95	2.00	15.00	15.00	1.00	4.00	2.00
94	2	1	0.70	2.00	15.00	16.00	3.00	4.00	2.00
94	1	0	0.70	2.00	15.00	16.00	3.00	4.00	2.00
95	2	1	0.70	2.00	15.00	20.00	2.00	4.00	2.00
96	2	0	0.35	2.00	15.00	20.70	3.70	4.00	2.00
97	2	1	1.05	2.00	6.20	9.70	1.00	4.00	2.00
98	2	1	1.15	2.00	7.50	8.00	1.00	4.00	2.00
99	2	1	1.35	2.00	5.00	4.00	0.50	4.00	2.00

Appendix B

METRIC CONVERSION FACTORS

1. Feet to Meters

1 foot = 0.3048 meters

Thus:

3 to 4-foot swells ≈ 1-meter swells,
a 16-foot boat ≈ a 5-meter boat, and
an altitude of 500 feet ≈ a 150 meter altitude.

2. Nautical Miles to Kilometers

1 nautical mile (nm) = 1.852 kilometers (Km)

Thus:

10 nm visibility ≈ 18.5 Km visibility, and
a 2 nm range ≈ 3.7 Km range.

3. Knots to Meters/second and Kilometers per Hour

1 knot = 0.5144 meters per second
1 knot = 1.852 kilometers per hour

Thus:

a 10-knot wind speed ≈ 5-meter per second wind speed, and
a 10-knot search speed ≈ 18 kilometer per hour search speed.

LMED

8